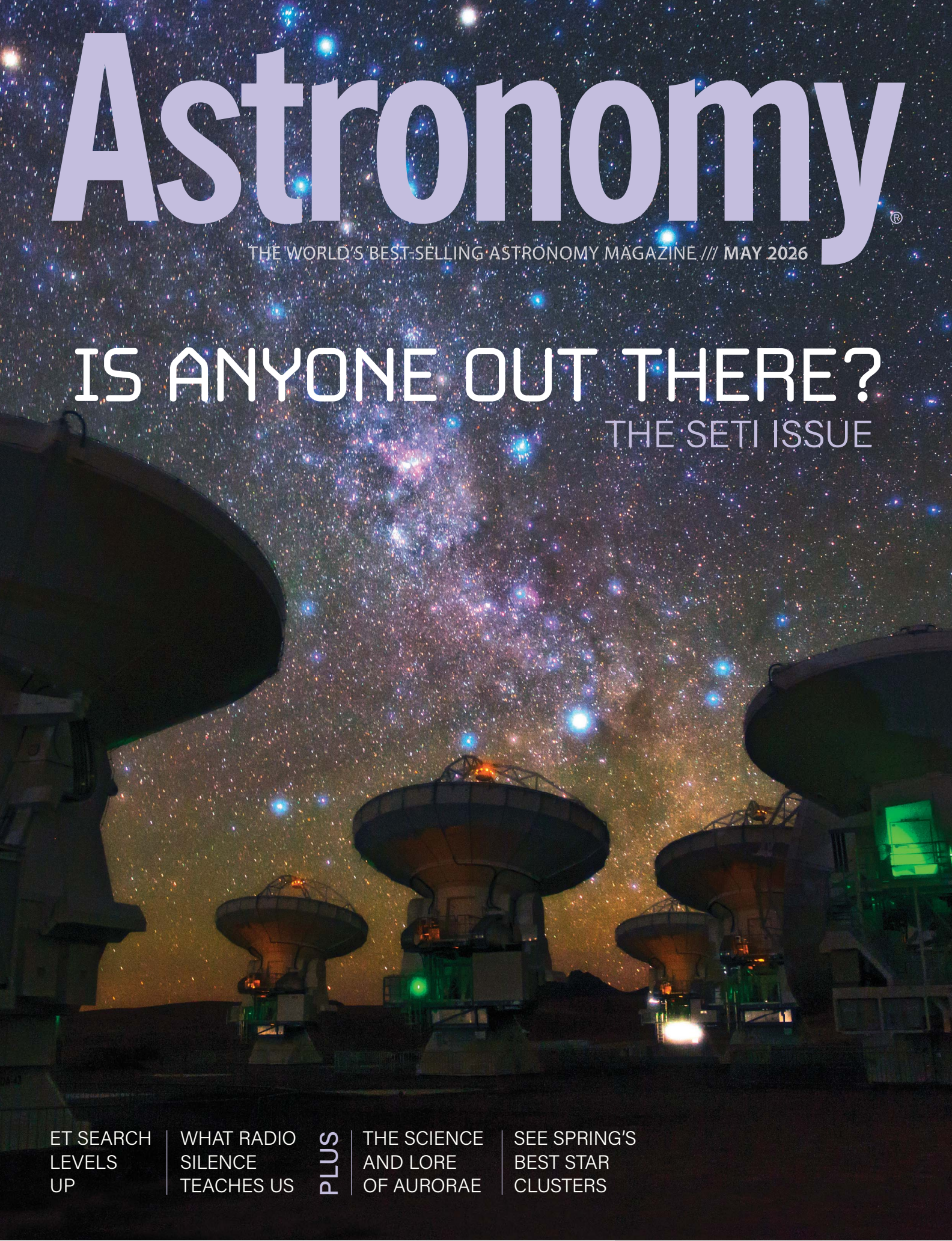
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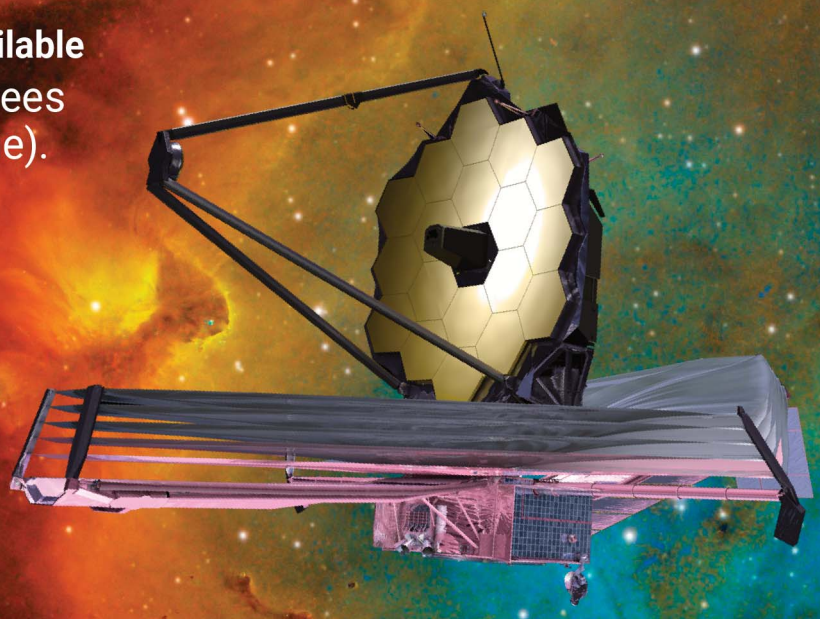

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MAY 2026
VOL. 54, NO. 5

ON THE COVER

We have not yet seen evidence of extraterrestrial life beyond Earth; nonetheless, the search is ramping up, fueled by new technologies.
ESO/B. TAFRESHI (TWANIGHT.ORG)

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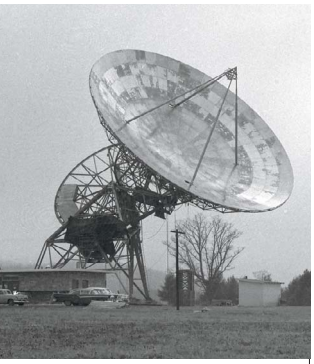

Opened in 1959, the 85-foot Howard E. Tatel Telescope was the first major radio facility at the Green Bank Observatory in West Virginia. Astronomer Frank Drake commandeered it in 1960 for Project Ozma — the first modern SETI experiment. NRAO/AUI/NSF

There are many ways we might discover an alien civilization. Perhaps we'll detect the artificial light from the nightside of an exoplanet, or infrared radiation leaking from a star-enveloping Dyson sphere.

But if we use Earth and human civilization as a reference point, by far the easiest way aliens with comparable technology could detect *us* is through our radio emissions, which we have been broadcasting into space for more than a century. This insight, articulated in 1959 by Philip Morrison and Giuseppe Cocconi, sparked the field that we now know as the search for extraterrestrial intelligence (SETI), using radio telescopes to listen for alien signals.

Throughout its history, SETI has struggled with a lack of funding — and results. But the search is just getting started, writes Ashley Balzer Vigil (page 14), fueled by a new generation of radio arrays and AI-driven data analysis. And while that doesn't guarantee a detection, on page 24 Laurence Tognetti explores what we learn by searching — even if we find nothing.

On another exciting note, I'm happy to say that we are hard at work refreshing both the print and digital sides of *Astronomy*. As we do so, we're keeping in our hearts and minds the motto on the masthead of our very first issue in August 1973: "The world's most beautiful astronomy magazine."

That means stunning print pages — but also a richer, more functional website and a smoother, more powerful app experience. If you're using an iOS device, you can already download our new app through the App Store, or go to Astronomy.com/iOSapp.

As part of these efforts, the July 2026 issue will see a first in the magazine's 53-year history. It will appear exclusively in our digital formats — on Astronomy.com and in the *Astronomy* app, rather than as a printed issue. The February 2027 issue will similarly appear only in digital formats. All subscribers will receive full access to these digital issues. They will include all the content you expect (and more) — features, departments, and Sky This Month. And the digital format will allow us to present them in beautiful, spacious layouts in the app and as enhanced multimedia experiences on our website.

I'll be direct: Yes, printing 10 issues a year instead of 12 saves money. But we are also investing in the paper quality and format of the print edition. The move will help us sustain our vision for a physical magazine that you will want to keep on your coffee table, with in-depth features and imagery that you'll come back to again and again.

Thank you for being loyal readers, and we look forward to sharing the results with you.

Mark Zastrow
Editor-in-Chief

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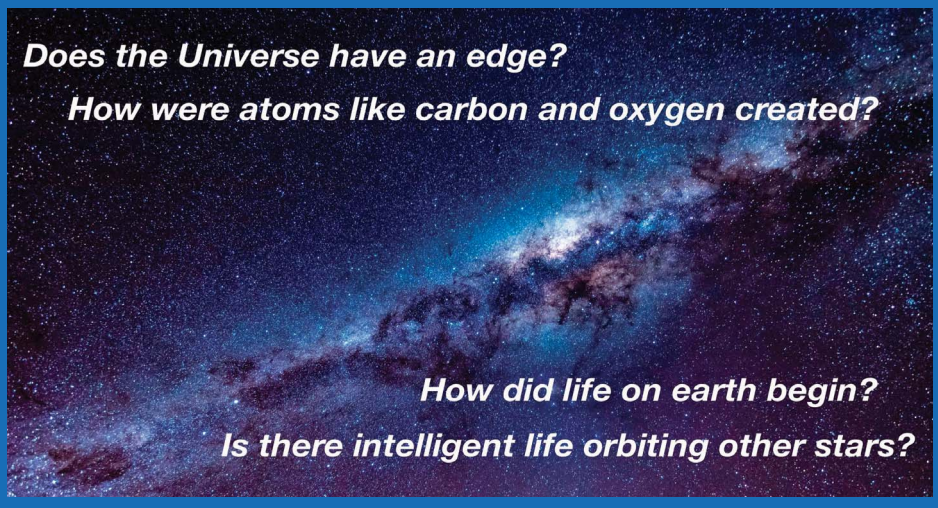
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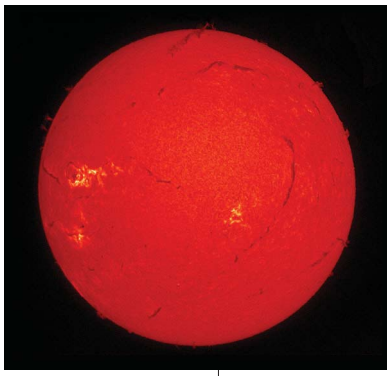
ASTRO LETTERS



The reddish Sun with dark filaments and bright plages is characteristic of an image from a solar telescope with an Hα etalon.
WARREN SPRENG

We welcome your comments via email to **astronomyeditorial@astronomy.com**. *Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Lee's star

I've been a subscriber for nearly 40 years, and very much into astronomy for 60-plus years now. So, I chuckled to myself when I saw the story of Tycho's star in "Stars lost to history" (December 2025). Around 1995, I was looking at Cassiopeia myself one night with just my eyeballs. I noticed a star there that I didn't recognize at all. I got out my Edmund *Mag 5 Star Atlas*, and there was no star there in the atlas! I ran inside to my in-laws and screamed, "I found a new star! I found a new star!" I imagined myself to be the first one to discover a supernova there. However, my in-laws thought I was nuts! Soon after, I got out my *Mag 6 Star Atlas*, and the star I saw was there after all. The *Mag 5 Star Atlas* had goofed; they put this star in the wrong place. Oops! I had to hang my head low the rest of the evening. **—Lee Nightingale,** Palm Desert, CA

Solar expectations

I enjoyed reading Mark Johnston's article on the advances in solar imaging (January 2026). His images are very dynamic and exciting. But I am a bit disappointed that not one represents the actual image that one sees when utilizing a solar telescope equipped with an etalon for the Hydrogen-alpha (Hα) wavelength.

A person who has not looked through one of these telescopes might be a bit surprised that the Sun does not present itself as a negative image or a yellow or orange color. Rather, the filaments are dark features against the disk and plages are bright, not black. The color is closer to a deep reddish orange visually. Here [at left] is an image from my Heliostar 76 (also reviewed in the January issue), which was taken with a mono Uranus-M camera from Player One and then colorized. **—Warren Spreng,** Mason, OH

Erratum

In No. 3 of our "Top 10 space stories of 2025" (February 2026), we misstated that dark matter is represented by the cosmological constant, or Λ. Rather, Λ represents dark energy.

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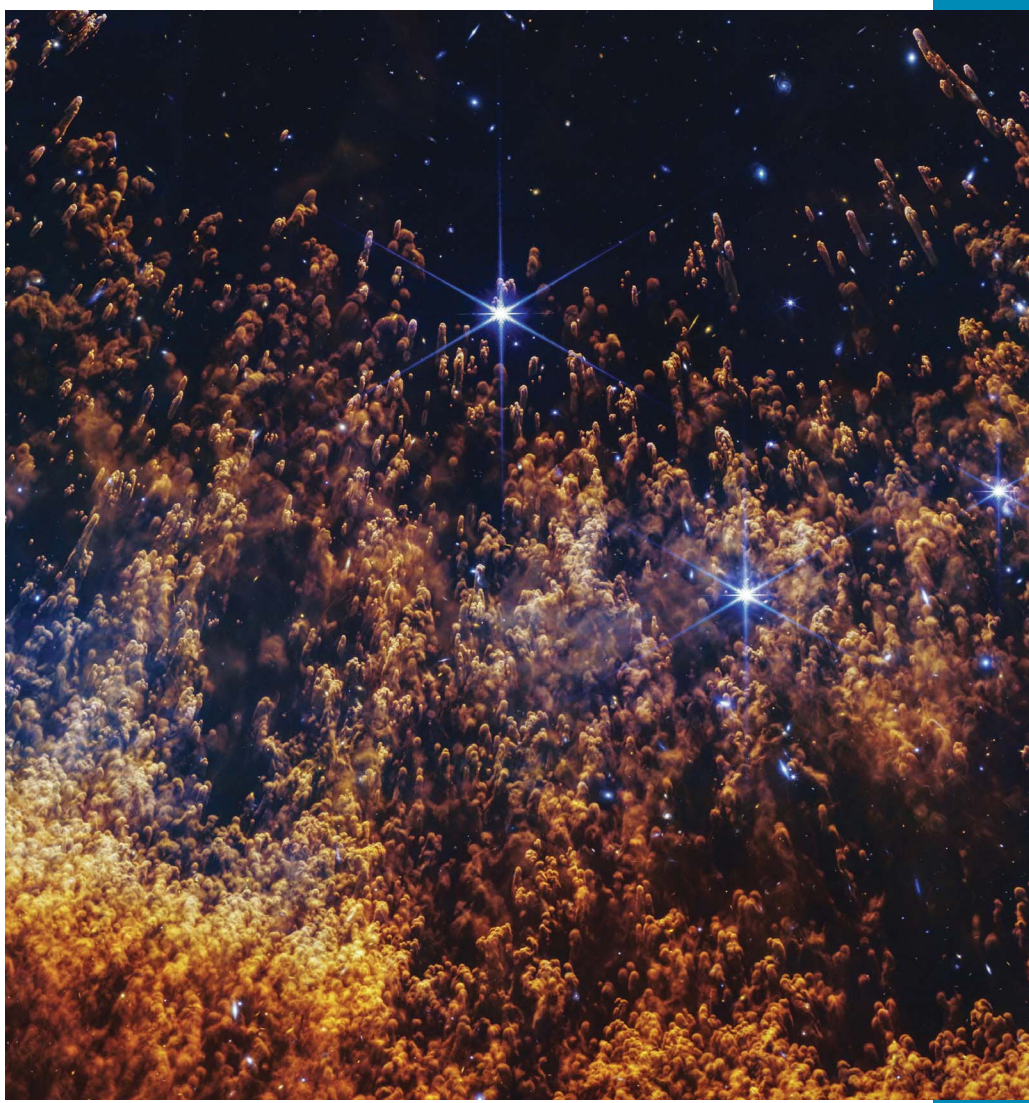
SNAPSHOT

JWST PEERS INTO THE HELIX

A planetary nebula's closeup reveals details in its expanding gas.

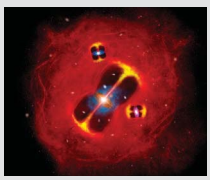


The Helix Nebula (NGC 7293) in Aquarius is a planetary nebula, created as a dying Sun-like star sloughs off its outer layers in an expanding shell. The Helix in its entirety appears like a two-dimensional ring. This view from the James Webb Space Telescope's (JWST) NIRCam instrument, however, zooms in on a portion of that ring, showing an arc along the nebula's outer edge (at bottom). The inner regions of the nebula are toward the top, with the white dwarf at the center of the nebula outside (above) this field of view.

The Helix is expanding from top to bottom here, as strong winds from the white dwarf smack into gas lost earlier in the star's life that has since cooled. Particularly noticeable are individual knots of gas in the shell. Color is used to show temperature: Blue is the hottest gas; middling temperatures appear yellow; and red regions are the coolest, thinnest gas. A few multipointed stars peek through the gas — these are background stars not associated with the nebula. —ALISON KLESMAN

NASA, ESA, CSA, STSCI/IMAGE PROCESSING: ALYSSA PAGAN (STSCI); BOTTOM FROM LEFT: LINGXIAO YUAN; NASA, ESA, CSA, STSCI; A. GINSBURG (UNIVERSITY OF FLORIDA), N. BUDAIEV (UNIVERSITY OF FLORIDA), T. YOO (UNIVERSITY OF FLORIDA)/IMAGE PROCESSING: A. PAGAN (STSCI); CC BY 4.0, UNIVERSITY OF SOUTHAMPTON

HOT BYTES



HEAT IT UP

The ALMA radio telescope saw hot gas filling a galaxy cluster 1.4 billion years after the Big Bang, when such gas should still be cool. This indicates galaxy clusters may undergo more violent births than previously thought, quickly heating intracluster gas.

X-RAY AFTERGLOW

XRISM space telescope observations of molecular clouds in the galactic center uncovered the afterglow of a powerful outburst from the Milky Way's supermassive black hole some 100 to 1,000 years ago.

GLOBAL COOLDOWN

A recent study found that a drop in dissolved calcium in seawater 66 million years ago caused the oceans to pull carbon dioxide from the atmosphere, cooling Earth by 27–36 F (15–20 C).

SCHMIDT SCIENCES TO FUND FOUR NEW OBSERVATORIES

The philanthropic organization will build a space telescope and fund three ground-based facilities.

DESERT ARRAY. Telescopes of the Deep Synoptic Array stand at the ready in the Nevada desert in an artist's rendering. The DSA is one of three ground-based facilities Schmidt Sciences will fund. K. MILLER, A. MEJÍA (DSA)

ON JAN. 7, the Schmidt Sciences organization — funded by former Google CEO Eric Schmidt and his wife, Wendy Schmidt — announced it will build a space telescope larger than Hubble and fund construction of three ground-based observatories. All four facilities, called the Eric and Wendy Schmidt Observatory System, should be operational by 2029.

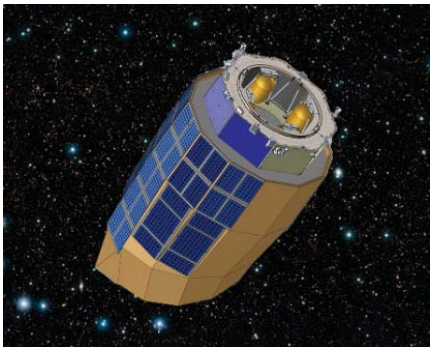
The news came at the annual winter meeting of the American Astronomical Society (AAS) in Phoenix and marks a major expansion of the Schmidts' philanthropic efforts in astronomy. "For 20 years, Eric and I have pursued philanthropy to seek new frontiers … committing our resources to novel research that reaches beyond what might be funded by governments or the private sector," said Wendy Schmidt in a statement.

WIDE-RANGING CAPABILITIES

A privately funded space telescope of this scale is unprecedented. Called Lazuli, its capabilities will "approach Hubble" but "for a ridiculously low price," said Pete Klupar, executive director of Schmidt Sciences and leader of the Lazuli engineering team, at the AAS session. Aiming to launch in 2028 with a 3-meter mirror and a coronagraph to block the glare of stars, Lazuli will observe exoplanets and study their atmospheres. It will also be designed to rapidly slew across the sky to catch cosmic explosions as they occur.

The ground-based facilities were previously in development by existing teams. The Argus Array, led by the University of North Carolina, will combine more than 1,000 small telescopes into one with roughly the collecting area of an 8-meter mirror, on par with existing large observatories. It will continuously observe the northern sky, quickly finding light from supernovae as well as events that create gravitational waves. The full array should be on sky in 2027, Argus team leader Nicholas Law said at the session, but he did not announce a location.

The Large Fiber Array Spectroscopic Telescope (LFAST) is designed for spectroscopy, including searching exoplanet atmospheres for biosignatures. Its mirrors are organized into subarrays of twenty 30-inch telescopes on a single structure. Team leader Chad Bender of the University of Arizona said the number of subarrays has not been determined. Each subarray has



SPACE SCOPE. Lazuli (seen in an artist's concept) is a privately funded space telescope larger than Hubble but will cost less, thanks in part to a shorter design cycle. SCHMIDT SCIENCES

the collecting area of a 3-meter telescope; they are aiming for the equivalent of a 30-meter-class telescope. The preferred site is Kitt Peak, with Mount Lemmon and Mount Hopkins as backups.

The Caltech-led Deep Synoptic Array (DSA) of 1,650 radio dishes will be built in Spring Valley, Nevada, using new astronomical radio receivers developed at Caltech that don't need complex cooling systems. The massive number of receivers will form a more complete combined beam than existing arrays, reducing the intensive data processing typically necessary to create radio imagery and allowing the capture of images in real time.

Arpita Roy, director of the Astrophysics and Space Institute at Schmidt Sciences, told *Astronomy* Lazuli will cost "hundreds of millions" of dollars. The combined budget for the three ground-based facilities is less than that, but "not small, either." All four projects are now officially proceeding.

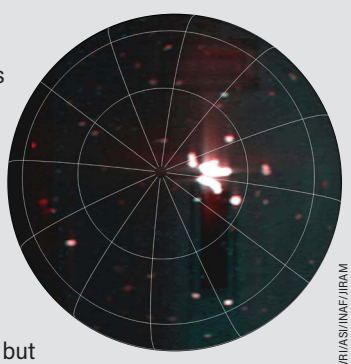
'COMPLEMENTARY AND ADDITIVE'

Schmidt leaders hope to show it is possible to build missions that embrace increased risk and launch quickly for less money. But the foundation does not intend to replace NASA missions or the National Science Foundation (NSF), which funds most U.S. ground-based astronomy. The projects are "meant to be complementary and additive," said Roy. She also said Schmidt is not intending to be a general funding agency.

Many astronomers were excited by the announcement. In particular, Schmidt Sciences' commitment to an open data model, with no reserved time for particular groups, is "very admirable," said Melodie Kao, a radio astronomer at the University of California, Santa Cruz. "One of the criticisms of private money is that you pick the winners and the losers. And so I commend them … for putting in the ground rules that the data will be public for everyone so that the whole community can benefit."

Kao also hopes the ground-based facilities will be funded for more than their announced lifespans of three to five years. "Pairing these observatories with the public assets built by NSF and NASA will be extraordinarily powerful," she said. "And also I hope that they'll be around for a while." – MARK ZASTROW

Io's most powerful volcanic eruption — ever



NASA/JPL-CALTECH/SWRI/ASI/INAF/JIRAM

TRAPPED BETWEEN the gravity of Jupiter and two of its fellow Galilean moons, Io is the most volcanically active body in the solar system. But a hot spot imaged in infrared light by NASA's Juno mission on Dec. 27, 2024, set a new record even for this amazing world. Located on the moon's southern hemisphere, the hotspot is larger than North America's Lake Superior. And according to NASA, its eruptions put out some six times more energy than all of Earth's power plants combined. Based on the data, researchers believe it isn't just one volcano, but several closely spaced ones, which indicates a huge system of magma chambers just beneath the surface there. Following the discovery, researchers tasked Juno with looking on future flybys for changes in the landscape caused by the immense eruption. – A.K.

QUICK TAKES

INNA IS OUTTA HERE

Energy giant AES Andes announced the cancellation of its controversial INNA project, which astronomers had warned would cause irreversible damage to the telescopes at ESO's Paranal Observatory and the Atacama Desert's dark skies.

NASA FULLY FUNDED

On Jan. 15, Congress passed a bill funding NASA with a $24.4 billion budget, rejecting the cuts proposed by President Trump, who signed the bill into law on Jan. 23.

SPONTANEOUS PEPTIDES

Scientists modeling the dust clouds where stars are born found that complex organic compounds like peptides — the precursors for proteins — can form spontaneously in space when simple molecules like glycine are bombarded by cosmic rays. This suggests the universe contains more of life's necessary building blocks than previously thought.

SHAKING THINGS UP

By collecting data from seismometers — originally designed to detect earthquakes — researchers can now track reentering space debris by the sonic booms it generates as it falls to Earth. This can help authorities quickly find debris on the ground and reduce potential contamination from hazardous materials.

ALAN SAYS 'ACHOO'

According to a new study, artificial light at night, or ALAN, can alter plants' biological cycles, making pollen season start earlier and last longer, increasing allergen exposure and posing a public health risk.

RUBIN MAKES HEADS SPIN

Among the 1,900 asteroids discovered in the First Look results released by the Vera C. Rubin Observatory last June, a new 0.3-mile-wide (0.5 kilometer) world was found to be spinning faster than any asteroid previously observed.

– BROOKS MENDENHALL

EARLY RETURN. On Jan. 15, NASA returned Crew-11 — seen here during pre-launch training — to Earth early following a medical situation involving one of the crew. From left: Oleg Platonov, Mike Fincke, Zena Cardman, and Kimiya Yui. SPACEX

Crew-11 comes home early

ON JAN. 8, NASA announced plans for the early return of Crew-11 — consisting of NASA astronauts Zena Cardman and Mike Fincke, Kimiya Yui of JAXA, and Oleg Platonov of Roscosmos — from the International Space Station (ISS) due to a medical issue with a single astronaut. A week later, on Jan. 15, the SpaceX Crew Dragon *Endeavour* splashed down with Crew-11 safely in the Pacific.

The decision marked the first early return of a crew in the ISS's 25-year history. During a Jan. 8 press conference, NASA Administrator Jared Isaacman stated that while the individual was stable, it was in the "best interest of our astronauts to return Crew-11 ahead of their planned departure." After the splashdown, Isaacman confirmed "the crew member of concern is doing fine."

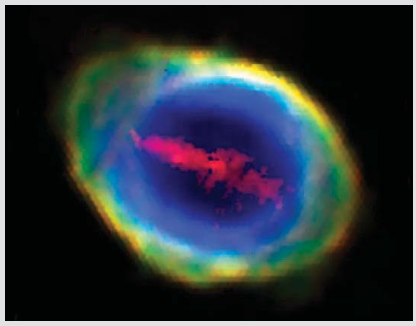
NASA Chief Health and Medical Officer J.D. Polk stressed during the same press conference that the issue was not related to the operational environment of the ISS. To protect the individual's privacy, further details were not disclosed, with Polk noting, "As a physician, I'm not going to speak about any particular astronaut or … diagnosis."

Polk emphasized that NASA has dealt with a variety of health issues on orbit for decades. However, the specific nature of this incident required diagnostic tools unavailable in space. "We have a very robust suite of medical hardware on board the [ISS], but we don't have the complete amount of hardware that I would have in the emergency department, for example, to complete a workup of a patient," Polk said.

Despite the early return, Isaacman declared the mission a major success, noting the crew completed 850 hours of scientific studies during their nearly 170 days in space. While the team was originally slated to return in late February, Isaacman emphasized during a Jan. 15 press conference that NASA was fully prepared for the contingency, stating the agency and its partners responded "quickly and professionally" to execute a safe return. – B.M.

ICONIC NEBULA SPORTS A HIDDEN BAR

Observations from the 4.2-meter William Herschel Telescope in the Canary Islands have revealed a hidden feature inside the famous Ring Nebula (M57). A mysterious bar-shaped cloud of ionized (excited) iron atoms (red) spans the Ring's interior, visible in this RGB composite image. The light of the outer ring comes from excited oxygen. The data were taken with the Large Integral Field Unit mode of the WHT Enhanced Area Velocity Explorer instrument. This mode allowed astronomers to break up the nebula's light into a spectrum "continuously across the whole nebula" to "create images of the nebula at any wavelength and determine its chemical composition at any position," said study lead author Roger Wesson of University College London and Cardiff University in a press release. This unique view revealed the mysterious bar. The team isn't yet sure of the bar's origins, but it might be a lingering clue to how the nebula was formed by its parent star. It could also be plasma residue from a vaporized planet that was caught in the central star as it expanded with age. – B.M.



ROGER WESSON ET AL./*MNRAS*

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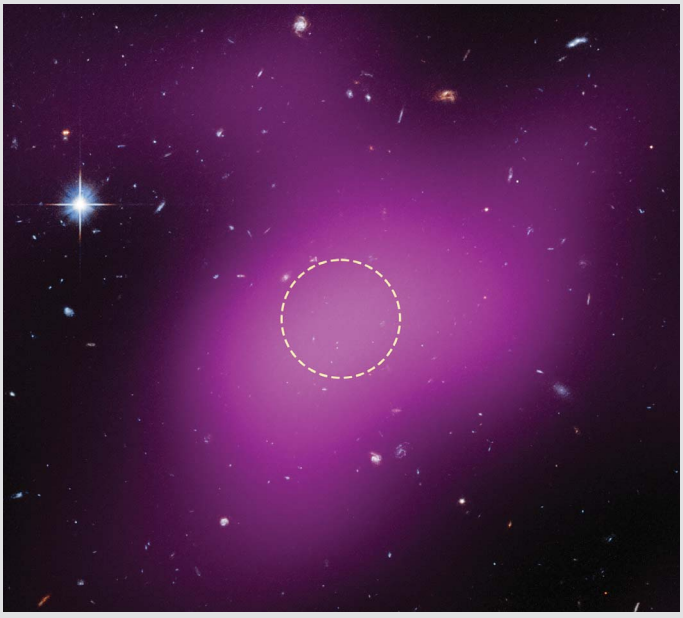
DEAD STAR MAKES WAVES

ESO/K. ŁUKIEWICZ AND S. SCARINGI ET AL. BACKGROUND: PANSTARRS

Space may seem empty, but images such as this prove it's not. Within the box at center is the star RXJ0528+2838, imaged with the Multi Unit Spectroscopic Explorer on the Very Large Telescope in Chile. Visible is gas flowing out from the star, which is compressed into a rounded bow shock at lower left by interactions with interstellar material as RXJ0528+2838 moves through space, orbiting within the Milky Way. This is the same mechanism that creates a curved wave ahead of a boat as it sails through water. The colors here represent different elements: red shows hydrogen, green shows nitrogen, and blue shows oxygen. Researchers believe the star has been spewing gas for some 1,000 years. But they aren't sure where that gas is coming from — RXJ0528+2838 is a white dwarf, the leftover core of a Sun-like star, and shouldn't be emitting gas on its own. Instead, it is pulling gas from a companion star, which should form a disk around the white dwarf. Gas from this disk could feed the bow shock, but astronomers see no such disk, leaving them wondering how such a "quiet" system has managed to form the structure seen here. –A.K.



NASA, ESA. G. ANAND (STSCI), AND A. BENITEZ-LLAMBAY (UNIV. OF MILAN-BICOCCA); IMAGE PROCESSING: J. DEPASQUALE (STSCI)

Astronomers on Cloud-9

A TEAM LED BY GAGANDEEP ANAND, senior staff scientist of the Space Telescope Science Institute's Advanced Camera for Surveys group, recently discovered Cloud-9 — a seemingly starless, compact cloud of hydrogen gas near the spiral galaxy M94, roughly 14 million light-years away. This composite image shows the glow of Cloud-9's gas at radio wavelengths (magenta), while the yellow circle is where the glow is brightest — and where astronomers used Hubble to look for stars, finding none. Cloud-9 appears to be a Reionization-Limited HI Cloud (RELHIC), a type of failed galaxy predicted by our standard cosmological model. A typical galaxy starts as a dark matter halo that gathers hydrogen gas, which eventually cools and collapses to birth stars. RELHICs are clouds of dark matter that pulled in some hydrogen gas — but not enough to form stars. As such, Cloud-9 serves as a bridge between theory and observation, confirming that a mass threshold exists for dark matter halos where galaxy formation becomes inefficient and unlikely. –B.M.

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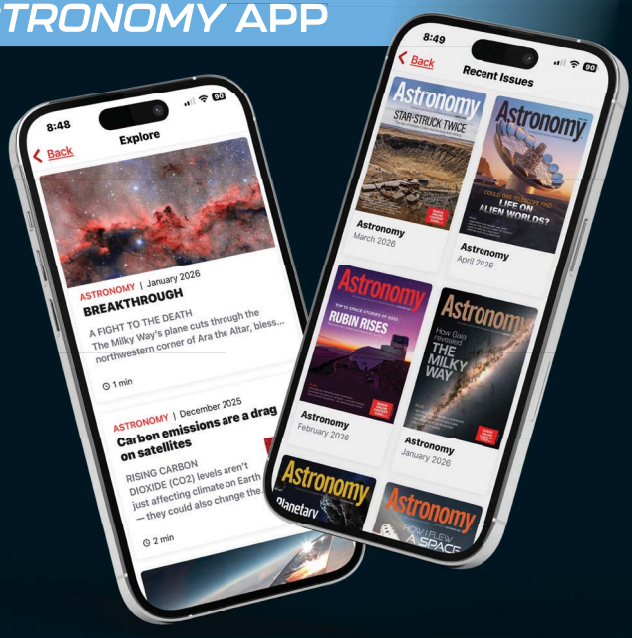

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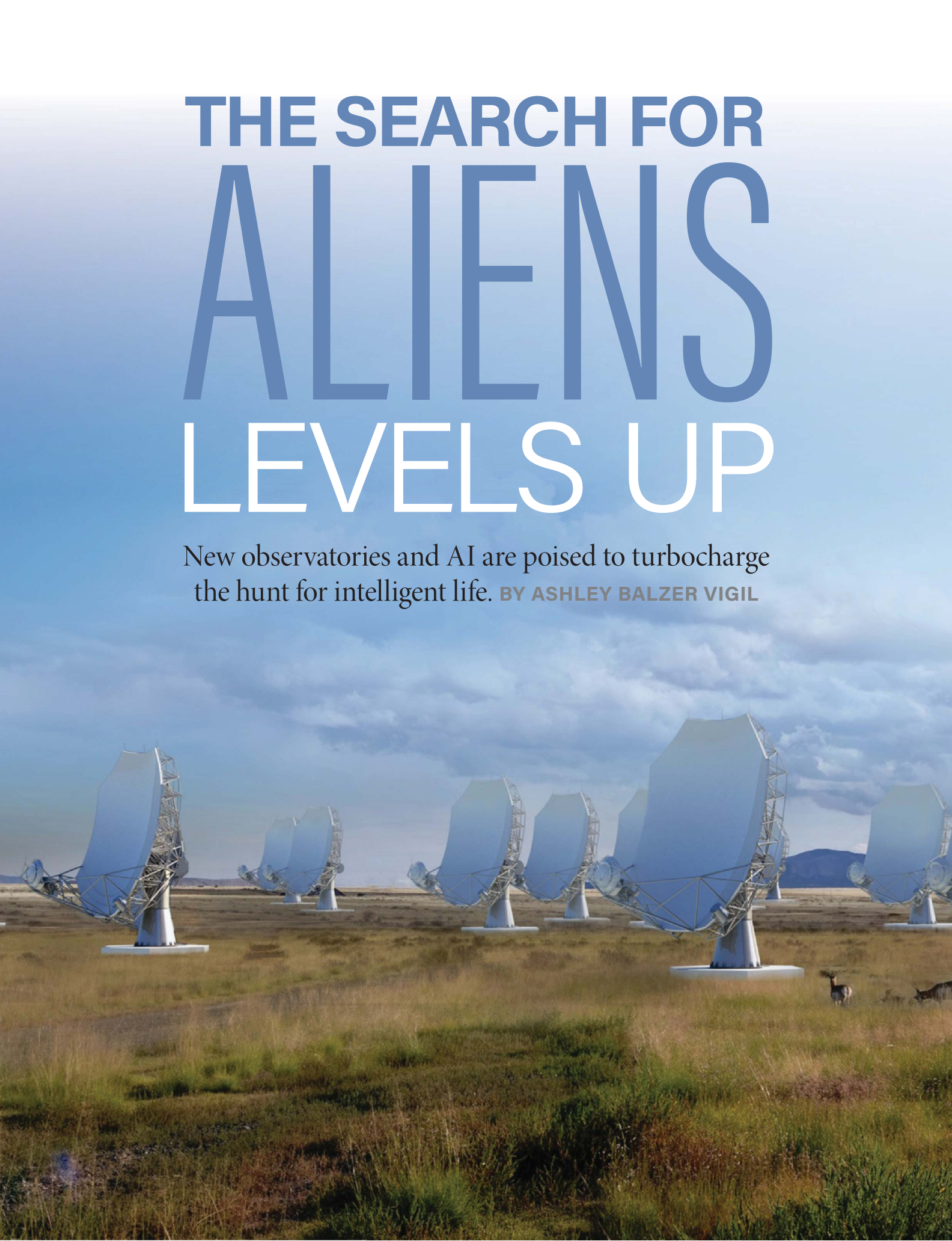
THE SEARCH FOR ALIENS LEVELS UP

New observatories and AI are poised to turbocharge the hunt for intelligent life. BY ASHLEY BALZER VIGIL

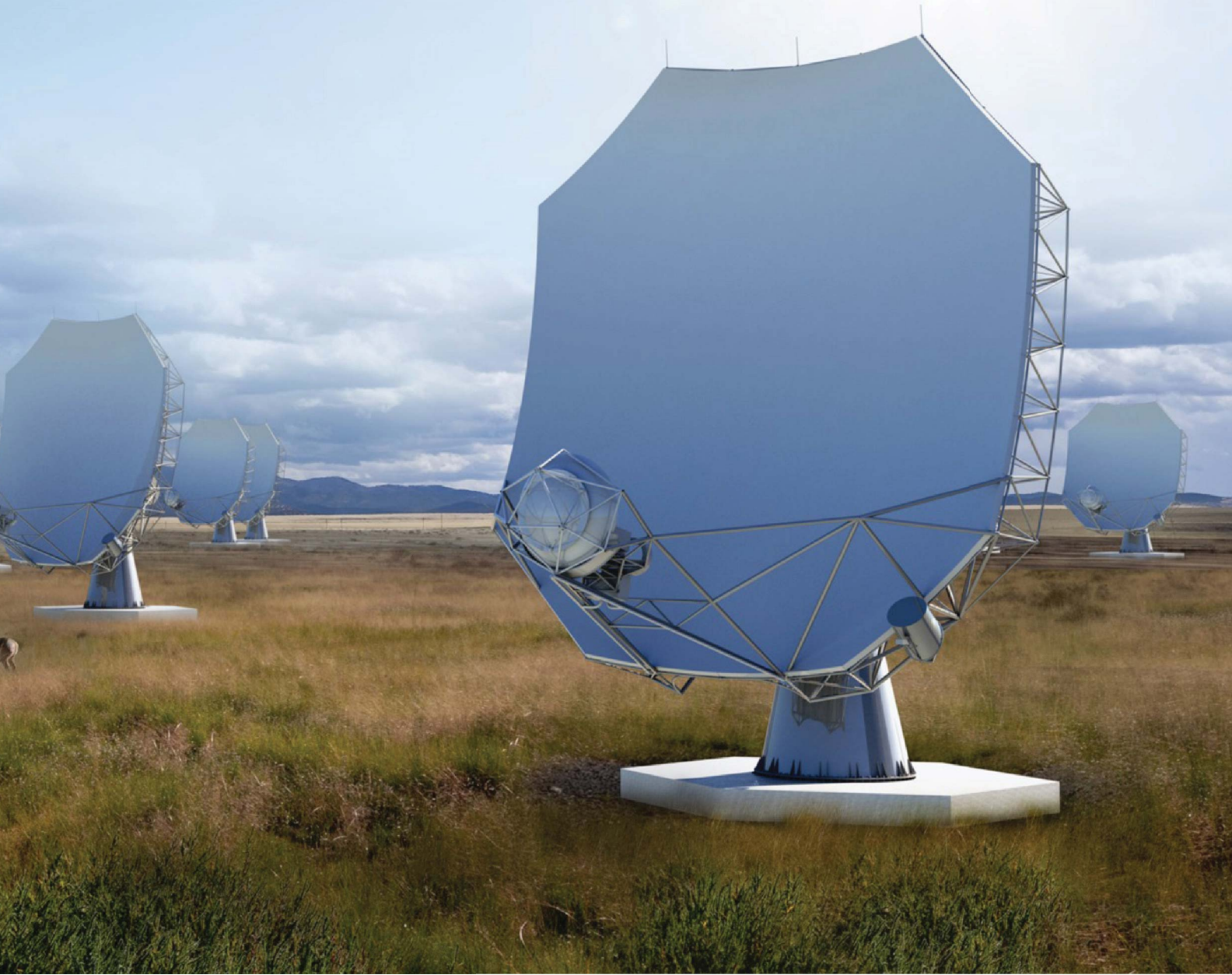


JUST OVER 40 YEARS AGO, in his novel *Contact*, astronomer Carl Sagan imagined what it would be like to detect radio signals beamed from other intelligent lifeforms in the galaxy. In the story, these extraterrestrial beings send blueprints to build a spaceship to carry a handful of Earth travelers to meet with them.

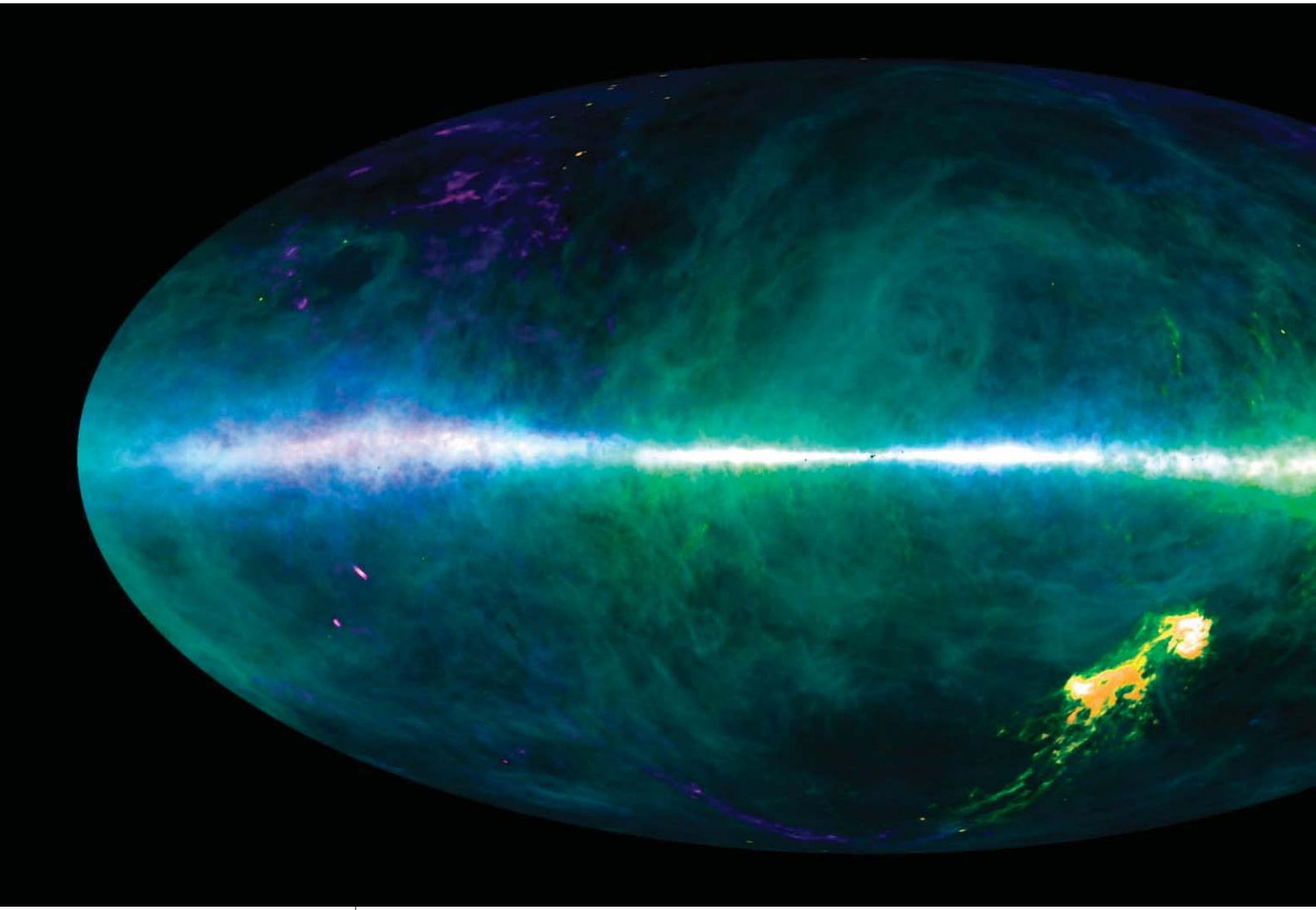
While the book lies firmly in the realm of science fiction, Sagan's expertise gave it a rare level of technical realism, offering a plausible sequence of events in which astronomers identify a radio signal of alien origin.

Yet after a century of listening, we are still alone in the vast cosmos — though that has not killed the hope that radio telescopes could open a line of communication to alien civilizations. In fact, we have barely begun to search the galaxy, having scanned only a fraction of its star systems. But that could soon change thanks to next-generation telescopes and AI-assisted data analysis.

The coming decade will see the biggest jump in search capabilities since the field began, raking in unprecedented torrents of data — a welcome development for astronomers. If we want to understand why we haven't found anything, "we need to do more of everything — expanded frequency ranges, broader sky coverage, more



Scheduled for completion in 2035, the next-generation Very Large Array in New Mexico is expected to be the most sensitive instrument for radio SETI in its frequency bands ever built. It will produce 40 petabytes of data each month.
SOPHIA DAGNELLO, NRAO/AUI/NSF



One of the most important frequencies in radio astronomy is 1420.4 MHz. Cold hydrogen atoms emit radio waves at this frequency when their electrons reverse the orientation of their spin. This so-called spin-flip transition occurs while the atom is in its ground state — it does not require the gas to be heated by a nearby star to a higher energy level. Though this emission is faint, it allows astronomers to map the structure of hydrogen clouds across the entire sky, seeing more than just the clouds that are lit by stars. The ubiquity of this emission has led SETI researchers to hypothesize that extraterrestrial civilizations might use the frequency as a hailing channel. BENJAMIN WINKEL AND THE HI4PI COLLABORATION

frequent and detailed observations," said Steve Croft, an astronomer at the SETI (Search for Extraterrestrial Intelligence) Institute and the University of California, Berkeley. "We haven't looked well enough yet to say much so far."

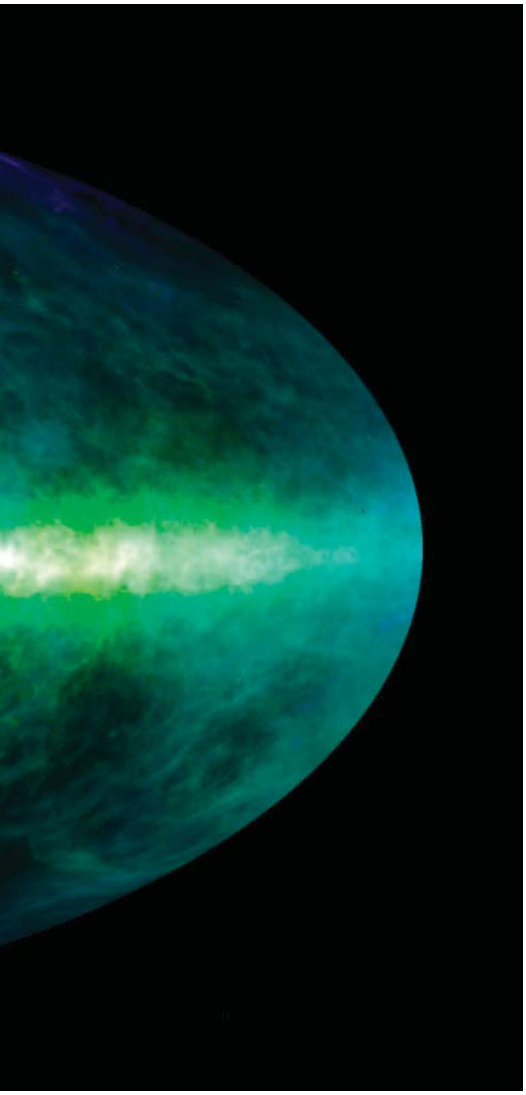
Radio static

When *Contact* was published in 1985, the SETI Institute had just begun its hunt. But scientists had already been searching the stars for alien radio signals for decades.

The first organized effort took place in 1924 during an opposition in which Mars and Earth made a particularly close approach to each other. Astronomer David Peck Todd convinced the U.S. military to ask their radio stations across the country to observe radio silence and listen for any unusual transmissions from the Red Planet. They even had cryptographers standing by to translate potential messages they picked up. Private broadcasters mostly didn't cooperate, and even military radio silence was patchy. The effort didn't turn up any alien signals, but it helped lay the foundation for later searches.

In 1960, the then-29-year-old astronomer Frank Drake kicked off the modern SETI movement using an 85-foot radio dish in Green Bank, West Virginia. He named the roughly $2,000 effort Project Ozma after the ruler of Oz — a place described as "very far away, difficult to reach, and populated by strange and exotic beings."

Drake singled out two stars to study — Tau (τ) Ceti and Epsilon (ε) Eridani, each 11 light-years away — using a radio receiver designed to home in with extreme precision on a single frequency channel. He and his small team spent six



hours each day for a few months listening over loudspeakers and monitoring a chart recorder tuned into 1420.4 megahertz, a frequency associated with hydrogen, the most abundant element in the universe.

It seemed a logical place to start: Like us, other advanced civilizations measuring large clouds of neutral hydrogen across the galaxy could detect their characteristic radio emission at 1420 MHz. Perhaps they might use it as a universal hailing frequency. Carl Sagan would later employ the idea as a plot point in *Contact*, when astronomers detect pulsing light from the Vega system at 1420 MHz that contains a message encoded in the universal language of math: a sequence of prime numbers, too specific to be produced naturally by any celestial object.

But no clear and obvious signals surfaced from the static as Drake and his team listened.

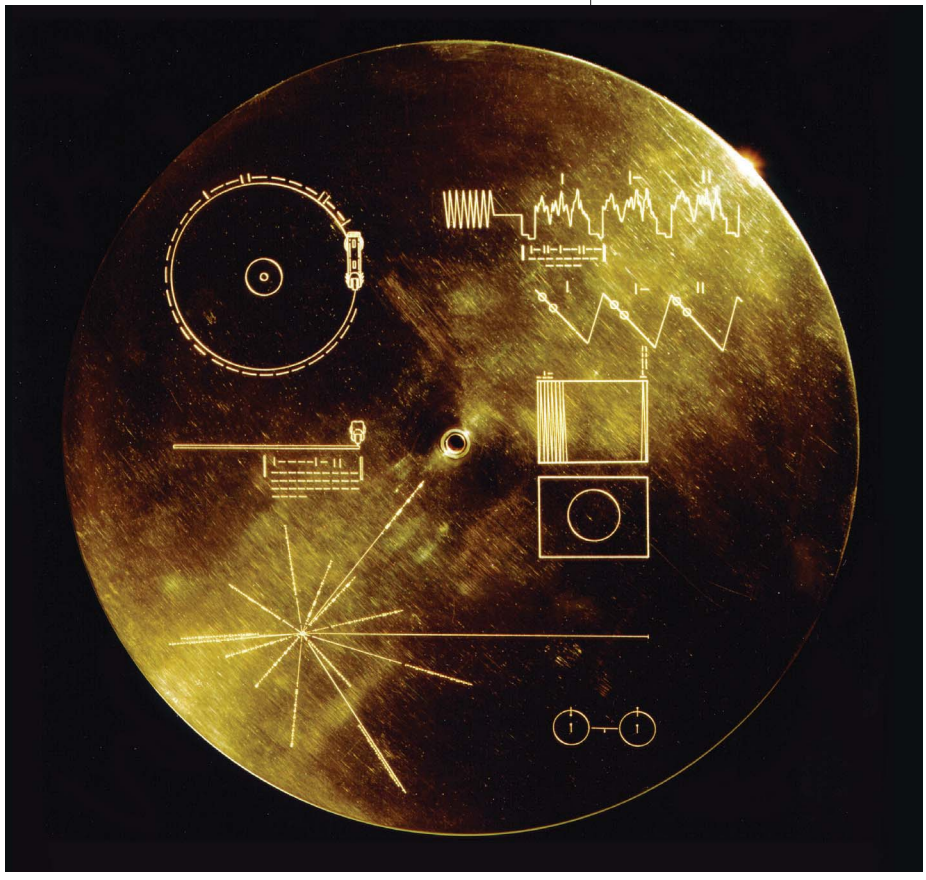
The field has made dramatic technological progress since 1960. "Instead of a single-channel receiver on an 85-foot telescope, we can now tune into a billion channels at once on the 330-foot telescope now at Green Bank," Croft said. Croft is also a project scientist for Breakthrough Listen, a project searching for extraterrestrial communications that is funded by Soviet-born Israeli billionaire Yuri Milner. "We've looked at thousands of targets with incredible frequency range at Green Bank alone," Croft said. "Combine that with other searches and we've looked at over a million stars, and done so with much greater computing power and better algorithms."

It's a big galaxy, though. Tally up all the searches conducted so far and it still only amounts to about 0.00001 percent of the Milky Way.

Hot mic

Part of the difficulty is that no one is certain exactly how we should be looking for alien signals.

"You might say it's like looking for a needle in a haystack, but at least in that



When the twin Voyager probes launched in 1977, each carried a copy of a gold-plated phonograph record featuring audio and video recordings from Earth. Their protective covers, pictured here, featured schematic explanations of how to play and decode the data (top and center); a map of the location of our Sun relative to 14 known pulsars (lower left); and a diagram of the spin-flip transition of the hydrogen atom which produces emission at 1420.4 MHz. The time period between passing wave crests at this frequency provided the reference unit for time periods in the other diagrams, which were expressed in binary. NASA/JPL

case you know what a needle looks like," Croft said. "And you know that there is a needle in the haystack."

Without that knowledge, astronomers have to cast a very wide net. Luckily, technology is helping to make it wider. Instead of relying on aliens to deliberately send messages designed for us to detect, astronomers now can also look for fainter signs of technology that might leak out from advanced civilizations.

Every radio transmission we've generated, from early Morse code communication to modern news and entertainment, travels far beyond Earth listeners; they radiate out into space in all directions, gradually weakening as they go. Because radio waves travel at the speed of light, our radio bubble now extends about 100 light-years from Earth.

Since the dawn of SETI, astronomers have mainly focused on looking for intentional radio messages sent by alien civilizations. But with new observatories, detecting radio leakage from other planetary systems is becoming a real possibility. Instruments like the Green Bank Telescope and Allen Telescope Array in Northern California search for both beacons and latent signals — including those resembling Earth-like broadband radio, radar, and even satellite emissions — from planets up to hundreds of light-years away.

And in the early 2030s, the Square Kilometre Array Observatory (SKAO) will come online. This facility, currently under construction, will consist of a pair of telescope arrays, one in South Africa and the other in Australia, collectively made up of hundreds of radio dishes and thousands of antennas. A 2025 study led by the SETI Institute's Sofia Sheikh found that SKAO would be capable of detecting signals like those broadcast by NASA's Deep Space Network to robotic spacecraft from a distance of 65 light-years. And it could pick up a deliberate message — comparable to those sent by the Arecibo Observatory — from a distance of 12,000 light-years.

"Originally the idea was to create a radio telescope that had enough collecting area that you could detect neutral hydrogen at redshift 1," said Michael Garrett, director of Jodrell Bank Centre for Astrophysics, which hosts the SKAO

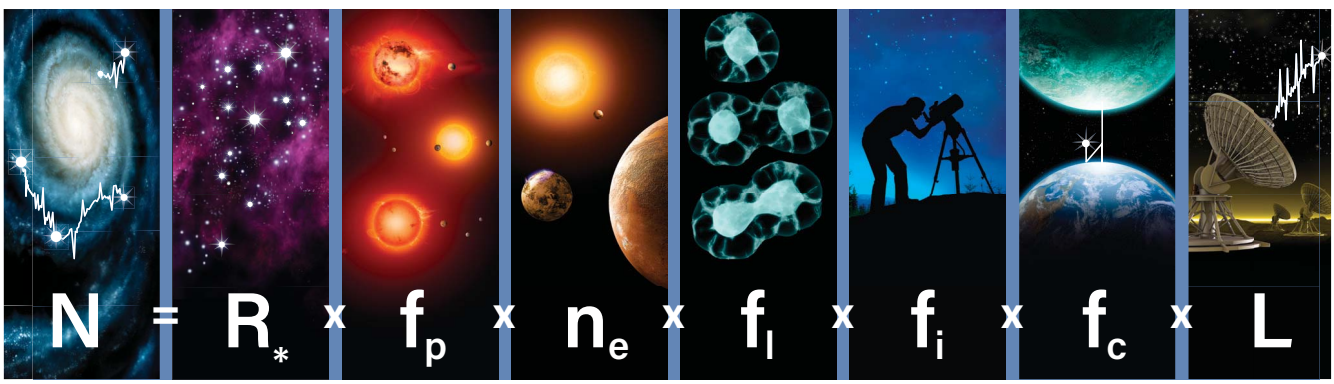
WHERE IS EVERYONE?

IN 1961, the year after he conducted Project Ozma, Frank Drake laid out an equation to understand how many technologically advanced civilizations there could be in our galaxy (*N*), and how likely we are to "hear" them: $N = R_* f_p n_e f_l f_i f_c L$

At the time, astronomers really only had a solid estimate for the first factor (R_*), which represents the number of new stars that form each year in the Milky Way, then thought to be around 10. So Drake filled in the rest with guesses just as a thought experiment: Assuming ⅛ to ½ of those stars host planets (f_p); at each planet-hosting star, one to five of those planets are habitable (n_e); 100 percent of those planets develop life (f_l); 1 to 10 percent of those life-bearing planets develop intelligence (f_i); 10 to 20 percent of those civilizations develop technology we could detect (f_c); and that civilizations last between 1,000 and 100 million years (L), Drake arrived at anywhere between a couple of dozen and 50 million possible communicating civilizations across the Milky Way.

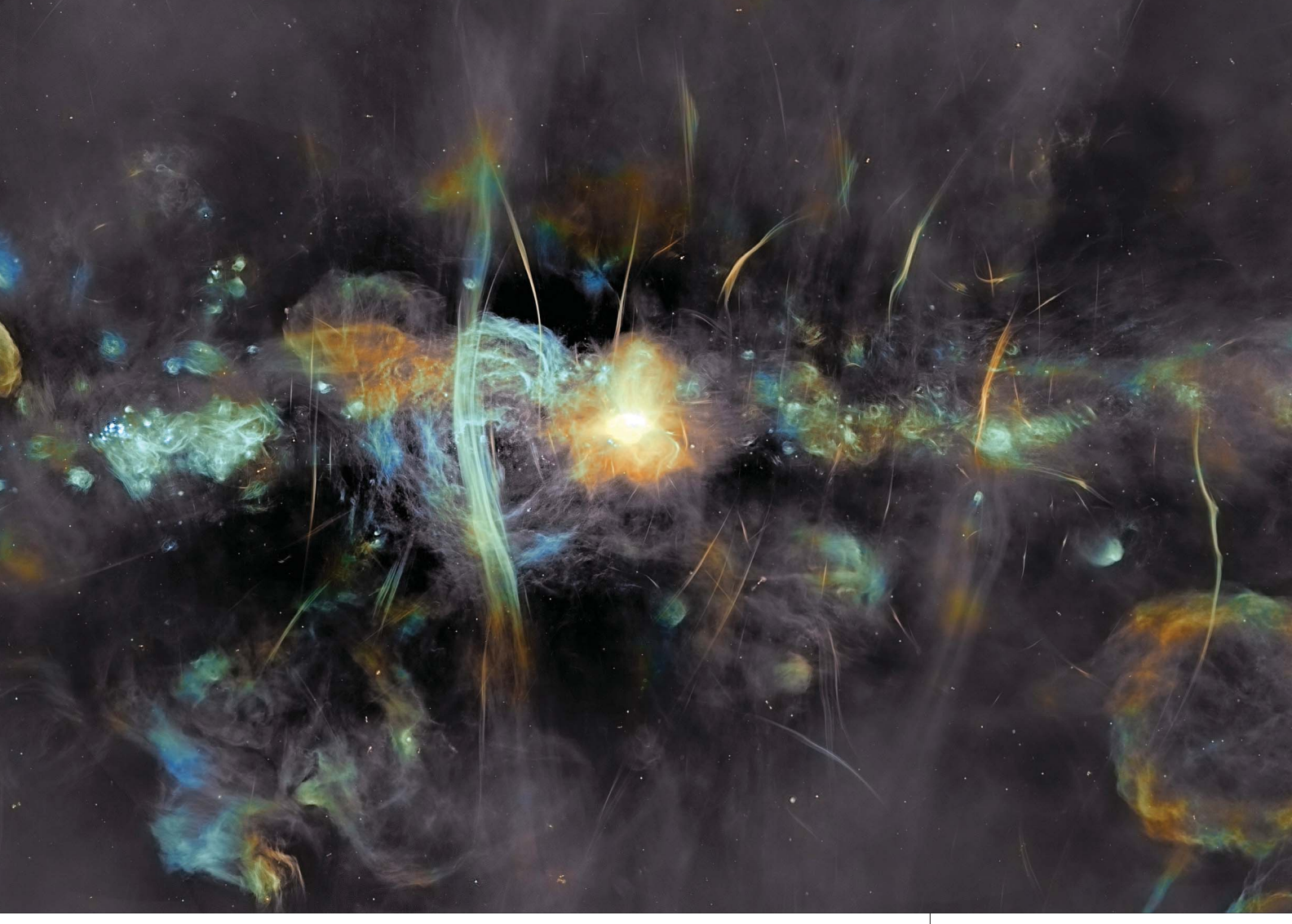
Modern measurements have brought a couple of those values down — our galaxy forms one to three new stars each year, and between 0.1 and 0.5 of planets are Earth-size and in their star's habitable zone. But we also now know that nearly every star in the galaxy has planets. The rest of the values remain unknown. Even with very conservative estimates, however, it seems so improbable that it's almost outrageous to think that we're the only beings in the galaxy capable of interstellar communication.

And yet … where is everyone? Fermi's Paradox describes the contradiction between the apparent high likelihood that other intelligent civilizations should exist in the Milky Way, and the fact that we can't seem to find a trace of them. Solutions to the paradox generally boil down to one of three explanations: Either they're not as common as we suspect, they don't last very long, or they're out there and we have yet to detect them. The answer could teach us invaluable lessons not only about other civilizations, but also the future of our own. *—A.B.V.*



ASTRONOMY: ROEN KELLY

The **number** of technologically advanced civilizations in the Milky Way	The **rate** of **star formation** in the galaxy	The **fraction** of those stars with **planetary systems**	The **number** of planets per solar system with an **environment** suitable for life	The **fraction** of suitable planets on which **life** actually appears	The **fraction** of life-bearing planets on which **intelligent** life emerges	The **fraction** of civilizations that develop a technology that releases detectable signs of their existence	The **length** of time such civilizations release detectable signals



Cutting-edge radio observatories have unprecedented sensitivity, as demonstrated in this image of the center of our galaxy taken by MeerKAT in South Africa — a precursor array to the larger Square Kilometer Array. This image, released in 2022, reveals striking, parallel radio filaments whose origins remain mysterious.
SARAO, HEYWOOD ET AL. (2022)/J. C. MUÑOZ-MATEOS

Headquarters. Redshift is a measure of how much the universe's expansion stretches the wavelength of light traveling through it. Redshift 1 is so far away that it's like looking nearly 8 billion years into the past. "But if you build a telescope that can do that, you can do all sorts of other things too," Garrett said.

Since it will take many years and ample funding to achieve an entire square kilometer of collecting area, the SKAO team is rolling out construction in stages. But even its first phase, at roughly 10 percent of the hoped-for eventual area, will be a generational leap over previous radio arrays.

SKAO is targeting neutral hydrogen because by tracing its distribution over time, you can see how it evolved to form stars and galaxies. The observatory will be capable of testing out fundamental physics on vast scales. But since it involves homing in on 1420 MHz for some observations (along with covering a broader range from 350 MHz to 15.4 gigahertz), it could just pick up a long-distance phone call of sorts as well.

Phase one is "basically a factor of five more sensitive than some of the big single dishes that have up until now dominated the kind of searching that we do for extraterrestrial intelligence," Garrett said. "And with a much larger field of view, it will see something like an order of magnitude more stars at any given time. So astronomers can comb through the data SKAO will already be getting for other purposes and look for signs of other life-forms, and I'd like to think we'll dedicate

IF WE'RE NOT ALONE, MIGHT THAT ENCOURAGE US TO SHAPE UP, DRAW TOGETHER AS ONE HUMAN SPECIES, AND PUT OUR BEST FOOT FORWARD FOR OUR GALACTIC DEBUTANTE BALL?

CONVERSATION STARTER

WHILE THERE ARE many proposed ways to detect signatures of alien technology, the easiest way for us to detect an Earth-level civilization is through radio waves. Our own TV, radio, and radar signals have been expanding into space for over a century — though they have only reached systems in a tiny bubble of the Milky Way.

1920
First commercial radio broadcast

1920

Alkaid
104 light-years

1927
First transatlantic plane flight

1930

Radio waves

1933
President Roosevelt's first "fireside chat"

Gamma Crucis
88 light-years

1940

1946
First jet to break the sound barrier

Regulus
79 light-years

1950

1957
First satellite, USSR's Sputnik

1960

Aldebaran
67 light-years

Delta Leonis
58 light-years

1969
Apollo 11 lands on the Moon

1970

Castor
49 light-years

1980
Cosmos premieres

1980

Capella
43 light-years

TRAPPIST-1
40 light-years

Arcturus
38 light-years

1990

Pollux
34 light-years

2001
Terrorists attack World Trade Center

2000

Vega
25 light-years

Altair
16.7 light-years

2010

Sirius A
8.6 light-years

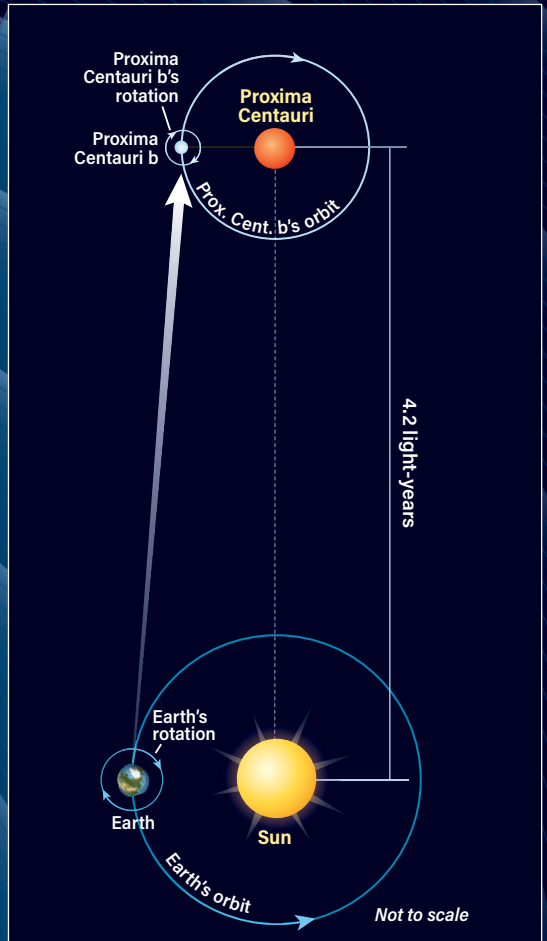
2020
COVID-19 pandemic declared

2020

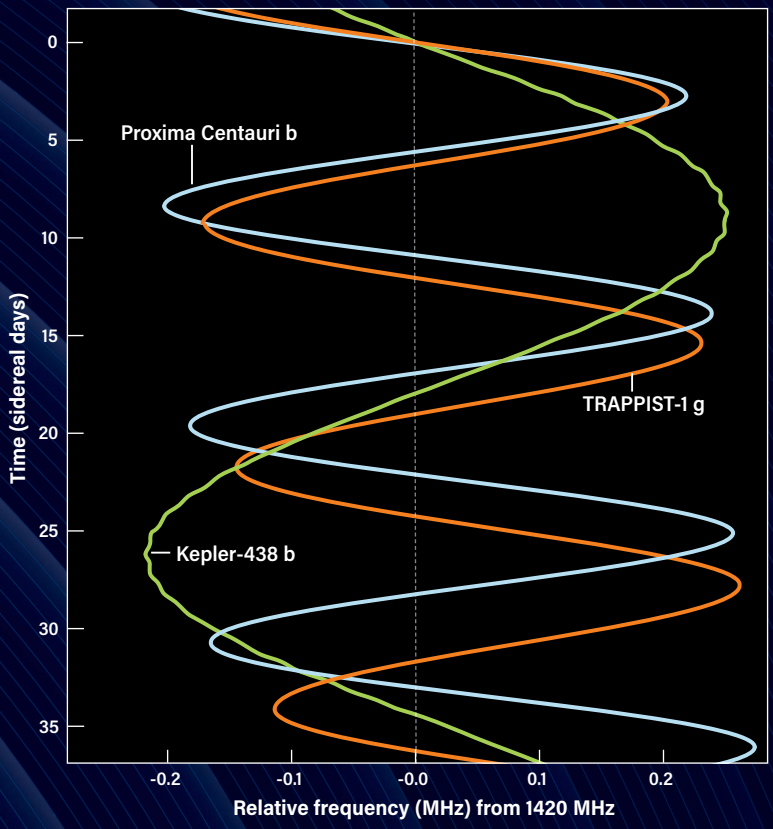
Proxima Centauri
4.2 light-years

Earth
2026

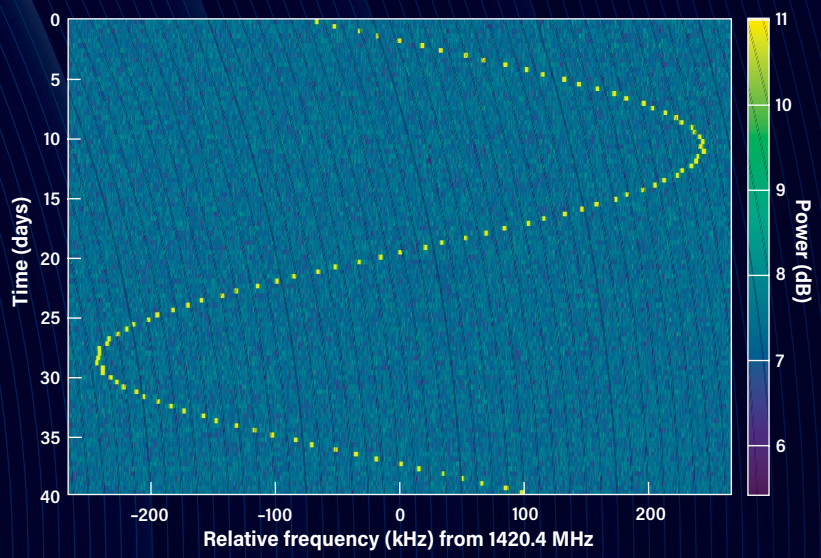
Earth and stars not to scale



If an alien civilization places a transmitter on their planet, both it and our ground-based radio telescopes will be moving toward and away from each other due to each planet's rotation and orbital motion around their respective host stars, as well our stars' relative motion through the Milky Way Galaxy. Like the rising and falling pitch of a siren passing by, the frequency of a received alien transmission will shift slightly in frequency due to the Doppler effect.



The calculated Doppler drift for transmissions from three exoplanets are displayed here as frequency shifts away from the hydrogen spin-flip transition line of 1420.4 megahertz. In these plots, the large sinusoidal curves are due to the orbital period of each planet, which ranges from 11 days to 35 days. The effect of Earth's rotation can be easily seen in the calculated curve for Kepler-438 b as a small daily squiggle; this is especially apparent partly because that planet is tidally locked to its host star, with its days as long as its orbital period.



This plot using simulated data shows what a radio signal from Kepler-438 b might look like, displayed in a format called a spectrogram. If a radio signal from a telescope aimed at this planet shows no drift at all, it could probably be ruled out as Earth-based interference.

ASTRONOMY: ROEN KELLY AFTER LI ET AL. (2022) HTTPS://DOI.ORG/10.3847/1538-4357/AC90BD

some time to [SETI observations] specifically at some point as well."

Missed calls?

But we may have actually detected a signal from other lifeforms already. It just may be buried in mountains of data.

"We're living in this era of Big Data astronomy, where we have a deluge of observations," Croft said. "We've come a long way from Project Ozma, where they had a pen recorder and did everything manually. We just can't do that anymore with a billion channels and millions of stars."

Astronomers have begun using AI to sift out all of the uninteresting stuff from huge datasets. Using machine learning to flag anything weird helps scientists search for signals on a scale that would have been unimaginable just 10 or 20 years ago.

While astronomers continue collecting potential signals, they're also busy developing new ways to analyze the ones they've already amassed. "I work with undergrads and I always tell them, you know, we may already have an alien signal on disk somewhere and one of you might be the one to write the algorithm that's smart enough to find it," Croft said.

To do so, an algorithm must first filter out humanity's signals. "When you do a SETI survey, then you get many, many SETI detections, but like 99.99 percent of them are radio frequency interference produced by our own radio systems," said Garrett.

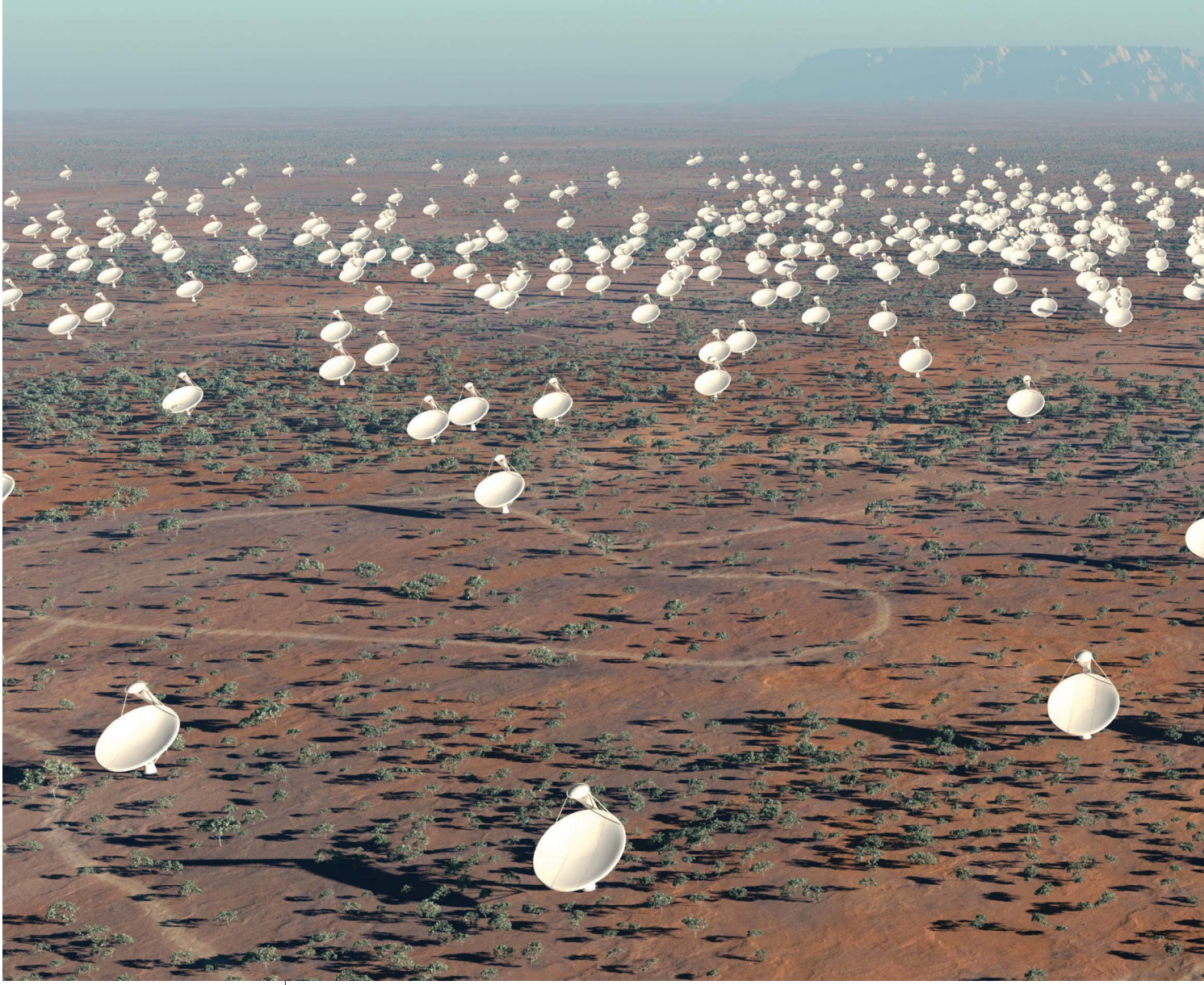
Astronomers often try to disentangle human-made radio signals from potential alien ones by exploiting the Doppler effect. Signals from space experience shifts in frequency due to Earth's rotation, orbit, and the source's own motion — what researchers call Doppler drift. Terrestrial sources typically show little to no drift, while satellites and planes produce characteristic patterns based on their movement.

But this analysis is still a difficult task, one that astronomers say AI will be very important for performing on larger datasets like those from the SKAO.

Making contact

Say we find a signal. Then we'll have to figure out what to do next. Should we reply? What would we say?

In 1989, the International Academy of



The name of the Square Kilometre Array refers to the project's ultimate goal of having dishes and antennas with a collecting area totaling 1 square kilometer. However, the project — pictured here in a photo illustration — will begin its science operations at roughly 10 percent that level. SPDO/TDP/DRAO/SWINBURNE ASTRONOMY PRODUCTIONS (CC BY 3.0)

Astronautics (IAA) established a post-detection protocol, beginning with a thorough vetting of the signal's source. The plan stipulates sharing information with the global scientific community, notifying international organizations like the United Nations Office for Outer Space Affairs, and waiting to reply until after a worldwide consultation.

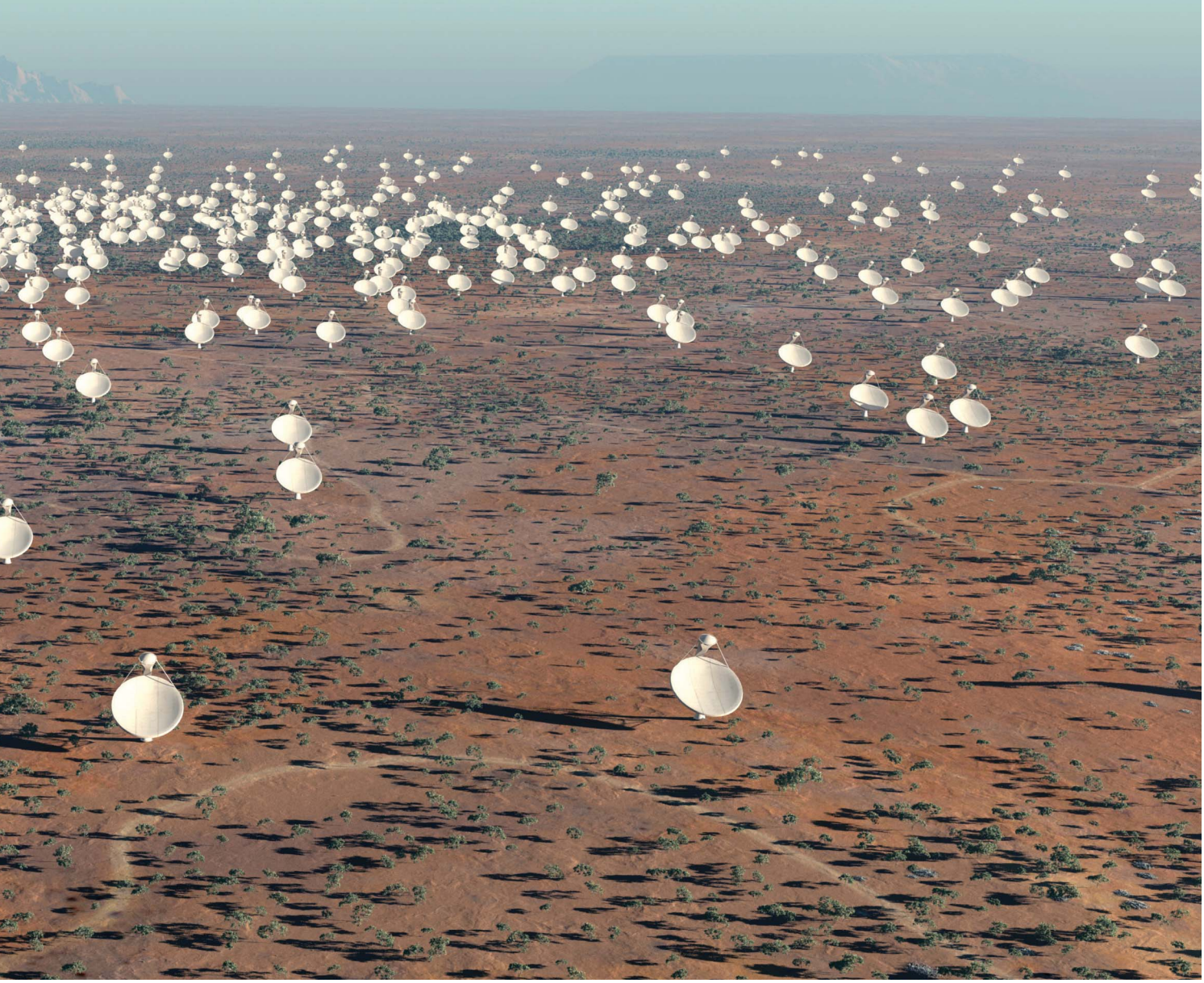
A 2010 update to the protocol made verification requirements stronger, clarified expectations for international coordination, and more firmly discouraged any reply from a single nation or organization. Still, enforcing such a restriction would be tricky: While amateur equipment is generally weak compared to professional facilities, anyone with a radio transmitter could send their own signal.

WHILE AMATEUR EQUIPMENT IS GENERALLY WEAK COMPARED TO PROFESSIONAL FACILITIES, ANYONE WITH A RADIO TRANSMITTER COULD SEND THEIR OWN SIGNAL.

The update also attempted to account for the internet, which was still in extremely early stages when the protocol was first adopted, and the recent rise of social media.

But Croft, who is also a member of the IAA's SETI committee, says that another update is in store. "The last revision was before things went viral on social media platforms," he said.

In 2010, less than half of U.S. households had social media. Now, that number has risen to include the vast majority



of Americans, and the trend is similar across much of the globe. And in their early days, social media platforms were usually designed to be friend-centric, whereas now content is often shared publicly for a global audience.

While different people are sure to prefer different approaches, "I think with such a big endeavor like this, the search has the potential to bring humanity together as a whole," Croft said.

It wouldn't be the first time SETI has drawn people together. Between 1999 and 2020, millions of volunteers from around the globe participated in a crowdsourced project called SETI@home. Participants downloaded software that ran in their computers' idle time, sometimes as a screensaver. This effectively gave the project access to a supercomputer in the form of the collective computing power from all the volunteers — essential to analyze the flood of data they were then gathering from the Arecibo Observatory in Puerto Rico.

Out of 12 billion flagged signals, 100 emerged as good candidates for a closer look. In July 2025, the SETI@home project leaders pivoted to follow-up observations using China's Five-hundred-meter Aperture Spherical Telescope (FAST). Time may tell whether any of them will bring us the revelation of a lifetime.

Whether we find that we are one Milky Way civilization among many or likely truly alone in the cosmos, the impact it has on humanity could be immense.

"For me, there's no other question that's more important than 'Are we alone in the universe?'" Garrett said. "That's the thing that gets me out of bed in the morning. If intelligent life is out there, would they be like us with the same ways of communication, the same ethics and morals, music and literature? What the hell would they even look like?"

If we're not alone, might that encourage us to shape up, draw together as one human species, and put our best foot forward for our galactic debutante ball? And if we are alone, shouldn't that make us value our planet more than ever? Could we really risk extinguishing all the life that has ever existed in the galaxy as a result of mindless wars and small-minded contentions? Perhaps we'll find that if and when we shape up, then our cosmic neighbors will come knocking.

Ashley Balzer Vigil *is a NASA science writer and freelancer with master's degrees in space studies and science writing.*

Should we keep

ABOVE: This section of the Great Observatories Origins Deep Survey, imaged by the Hubble Space Telescope and capturing thousands of galaxies, shows just how vast the universe is — suggesting some of the many challenges in reaching out to others. NASA, ESA, THE GOODS TEAM, AND M. GIAVALISCO (UNIVERSITY OF MASSACHUSETTS, AMHERST)

RIGHT: The Allen Telescope Array is designed to listen for signals sent or generated by extraterrestrial life. It has been used in SETI searches since 2007. SETH SHOSTAK/SETI INSTITUTE (CC BY 3.0)

Humanity has spent eons looking up at the stars and wondering whether we're alone, or if there are others like us out there in the vast unknown. Our curiosity has only increased as we have become a technological civilization capable of scanning the heavens for potential signs or signals from other civilizations, called technosignatures. But despite our advancements and intensive searches, we have yet to receive a definitive signal from intelligent life beyond Earth.

Why is that? What does the silence tell us? And what would it mean if we stopped listening?

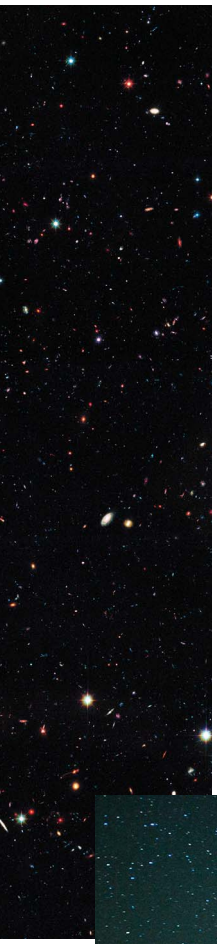
The Great Silence

We have been listening for aliens since the late 19th century, when inventor Nikola Tesla attempted to pick up artificial radio signals from Mars. Since 1984, the SETI Institute has scanned for signs of intelligence beyond Earth. But, despite hundreds of millions of dollars in funding for decades of searching and data analysis, their efforts have been met with silence.

"SETI has had a tumultuous past as a science," admits Chenoa Tremblay, SETI Institute project scientist for the Commensal Open-Source Multimode Interferometer Cluster (COSMIC). From the 1970s to the 1990s, she says, some of the search was federally funded in the U.S. with requests put in through NASA and the Jet Propulsion Laboratory, but these programs had "a narrow perspective" and remained disparate and uncoordinated. "Since [federal] funding [for the SETI programs] ceased in the 1990s, it has been an endeavor taken on by only a few dedicated individuals and has been under much scrutiny."

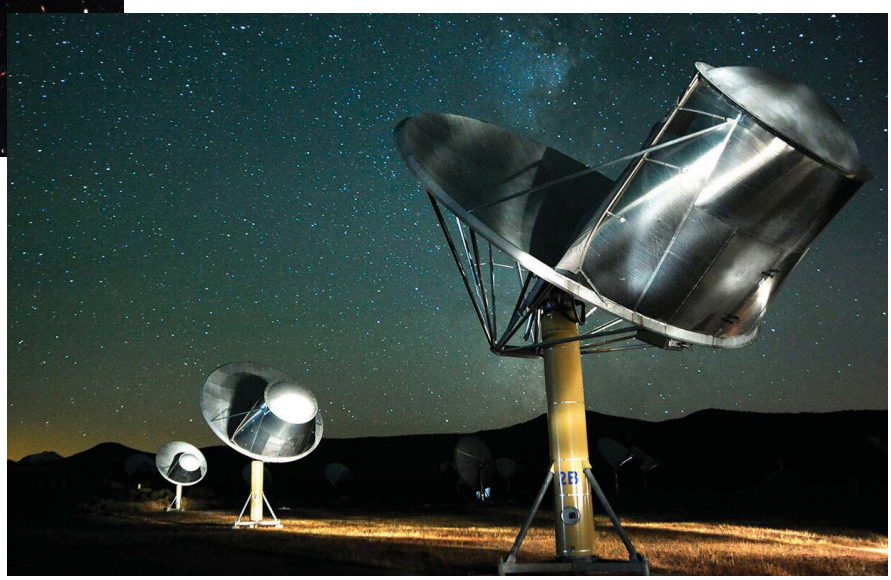
Scientists currently estimate that life began on Earth between 4.1 billion and 4.3 billion years ago. And the Milky Way Galaxy is currently believed to contain hundreds of billions to trillions of planets. Of the more than 6,000 confirmed exoplanets, approximately 200 are

looking for ET?



Despite decades-long searches, we have not yet found signs of extraterrestrial life. Is there value in finding nothing?

BY LAURENCE TOGNETTI



Earth-sized. These numbers alone could mean the Milky Way is teeming with life, and even intelligent life.

But the ongoing search for that life has its fair share of skeptics. Many cite the Fermi Paradox, which arose from a 1950 discussion in which physicist Enrico Fermi asked, "Where is everybody?" — meaning that given the age of the Milky Way, aliens should have already visited Earth. And yet they hadn't.

Over the ensuing decades, the Fermi Paradox — sometimes called the Great Silence — has become central to the debate surrounding SETI. Today the Fermi Paradox encompasses not just the lack of alien visitation, but the general contrast between the likelihood we are not alone and the lack of contact thus far with other civilizations.

Scratching the surface

Many proponents of SETI say the lack of alien signals can hardly be taken as evidence that no alien civilizations exist.

"There is no Great Silence," says SETI Institute technosignature research scientist Sofia Sheikh. "If you imagine the amount of space to search as the size of all of Earth's oceans, we have currently searched the equivalent of a small swimming pool's worth of water."

That was the conclusion of a 2018 study led by Penn State University astronomer Jason Wright that considered several factors, including the volume of sky that has been searched, the frequencies and bandwidths that have been scanned, and how frequently we've looked at a given target.

"We have not seen anything yet, but

SOLVING FERMI'S PARADOX

IF WE ASSUME that enduring alien civilizations are plentiful in the galaxy, we are left with three general explanations for why they haven't visited us.

First, perhaps interstellar travel is indeed too steep a challenge to overcome. Even if many of the challenges associated with covering the vast distances between stars can be solved with advanced engineering, biological challenges such as lifespan versus travel times arise.

Second, with the great travel times required between stars or across the galaxy, perhaps interstellar travel is possible but other civilizations that have undertaken it have simply not yet reached us.

And third, it is possible that alien civilizations may be capable of visiting us but have not made the effort. This could be because their society is too disorganized to make a concentrated effort; because it is politically unpopular or the fiscal investment required is undesirable; or even for ethical or other societal reasons, such as a desire not to interfere with other species. *—L.T., Alison Klesman*

SHOULD WE REACH OUT?

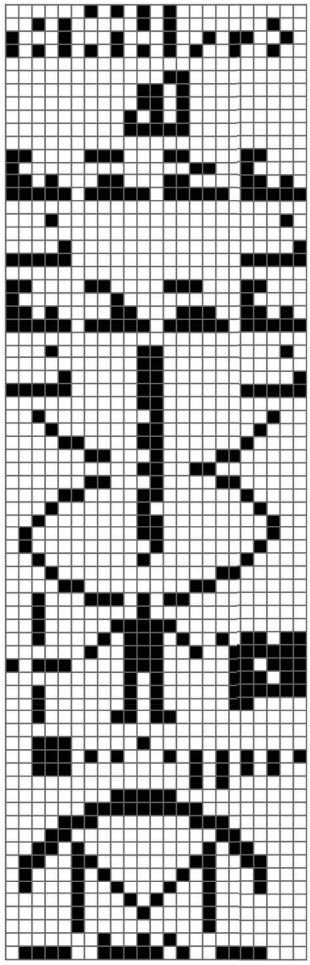
RATHER THAN WAITING for a signal to come to us, the field of active SETI, sometimes called messaging to ET intelligence or METI, does exactly that, sending messages of our own out into the stars in the hopes that another civilization might see them. The famous Arecibo message, a radio signal sent from the Arecibo telescope toward the globular cluster M13 in 1974, is one example. However, these efforts have not come without criticism.

SETI Institute emeritus board member John Gertz sums up much of this criticism in a 2016 study, writing that current METI attempts are "unwise, unscientific, potentially catastrophic, and unethical." Because we know nothing about other civilizations, he writes, we have no scientifically sound basis for assuming aliens are altruistic versus malicious. "SETI experiments seek to learn what actually resides or lurks out there in the universe. METI plays Russian roulette without even knowing how many bullets are in the chamber. It would be wiser to listen for at least decades if not centuries or longer before we initiate intentional interstellar transmissions, and allow all of mankind a voice in that decision," Gertz concludes.

Jill Tarter, longtime SETI scientist and now Chair Emeritus for SETI Research at the SETI Institute, told *Business Insider* in a 2016 interview that she believes the more advanced a society becomes, the less warlike and more cooperative it becomes as well. So, she posits, advanced alien civilizations are not likely to pose a threat. However, Tarter added that she also thinks we are not yet ready to send signals of our own: "I think that when we grow up and are an advanced technology, and can take on very long-term projects, then we ought to begin transmitting," she said in the interview. "But at the moment, in our very youthful state as an emerging technology, we should listen first." —*L.T., A.K.*

we have also barely scratched the surface of the search," says Sheikh, a former student of Wright's.

"The search so far has only looked through a straw in a few different ways and only a few times," says Tremblay. "We have not searched enough and in enough ways to even cover the parameter space of what we know a signal could look like if we generated it, let alone thinking far beyond our own understanding of what a signal could look like."



This is a visual depiction of the Arecibo message, a radio signal sent toward the globular cluster M13 in 1974. It is an example of active SETI or METI, in which humanity intentionally attempts to send signals to other civilizations, rather than waiting for alien messages to reach us. PENGO/ WIKIMEDIA COMMONS (CC BY-SA 3.0)

"Really, the effort for the search has kicked off over the last 10 years, with huge strides in progress," says Tremblay. "With the development of faster computers and willing collaborations with telescope facilities, we have only just begun a real search." (See "The search for aliens levels up," page 14.)

Recognizing a signal

Yet even if we succeed in scanning the entire sky and possible parameter space, it might not be simple to recognize an alien signal with our current technology. What if the nearest civilization is using laser communications or quantum teleportation? What technology would a civilization even 50 years ahead of us be using? What about a civilization 1,000 years beyond us?

"There is enormous difficulty in attempting to diagnose and predict the culture and communication for an advanced alien civilization," says Stephen Kane, a professor of planetary astrophysics at the University of California, Riverside. "A common issue is that people frequently imagine that technology has peaked, and so conceptualize advanced technology within that same framework, meaning similar technology but on a much larger scale." But, he points out, "were you using GPS from a cellphone 20 years ago? What technology do you imagine that you will hold in your hand 20 years from now?"

Kane continues: "In many ways, our current civilization is very much an alien entity to our own species of 100 years ago. Would humans of the 1920s have predicted our current culture and communication? How, then, do we anticipate the methods and motivations for a completely different species that is many thousands of years more advanced than us? It is a difficult problem to solve, but ideas on how to solve it will track our own technological progress, and with it our imagination."

What being alone means

But say that in the coming decades or centuries, despite our progress, still we find nothing. What would that silence teach us about the evolution of life throughout the galaxy?

If in fact alien civilizations are rare, there are two common scenarios postulated, says Tremblay. "One is that we are the oldest civilization. Life exists, but in a primitive form. Dinosaurs may have been great at survival, but they didn't build radio communication devices. Maybe there are other worlds out there with dinosaurs. The other is that we are the youngest. In this scenario, we are the last surviving civilization. If this is the case, we would expect to be able to find some form of leftover technology, but we may not know what we are looking for."

In the latter case, civilizations may not be rare, but short-lived. Numerous studies have attempted to explore the Great Filter, a longstanding hypothesis for why the number of technological civilizations might be limited throughout the

universe. Originated by economist Robin Hanson of George Mason University, the Great Filter breaks down the process of any given life-form developing into a spacefaring civilization into nine separate steps. These range from requiring the right type of planet and star system to support life to developing cellular biology, to achieving sentience and ultimately reaching the technological capability to colonize the galaxy. The hypothesis then proposes there must be a "barrier" that life cannot (or can only very rarely) overcome to reach the last stage and initiate travel across the galaxy. Perhaps it is extremely difficult to for life to develop, or for that life to become intelligent — or it is possible to reach humanity's current level but impossible to take the next step to interstellar travel.

Put simply, either life is rare or civilizations self-destruct before reaching a crucial stage of detection. A June 2024 study published in *Acta Astronautica* by Michael Garrett, director of the Jodrell Bank Centre for Astrophysics in the U.K., posits that the development of artificial intelligence (AI) is the Great Filter. He suggests that AI limits the longevity of technological civilizations to less than 200 years, ending them before they can achieve interstellar communications or travel: Either weaponization of AI leads to self-destruction, or AI eventually becomes "superintelligent" and its goals no longer align with its creators', so it eliminates them.

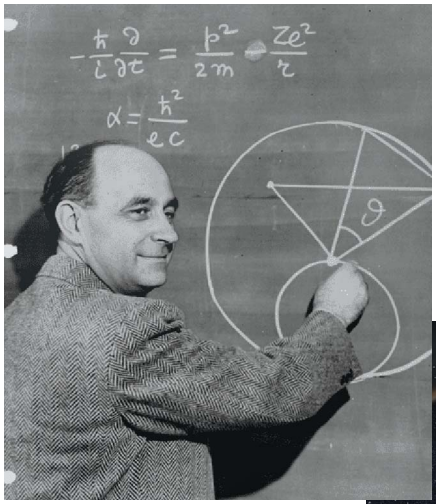
Keep looking

One simple question that arises is whether we can justify continuing SETI operations if we haven't found anything. And if we decide to give up, could it hurt or help us as a species? Will it divide or unite us?

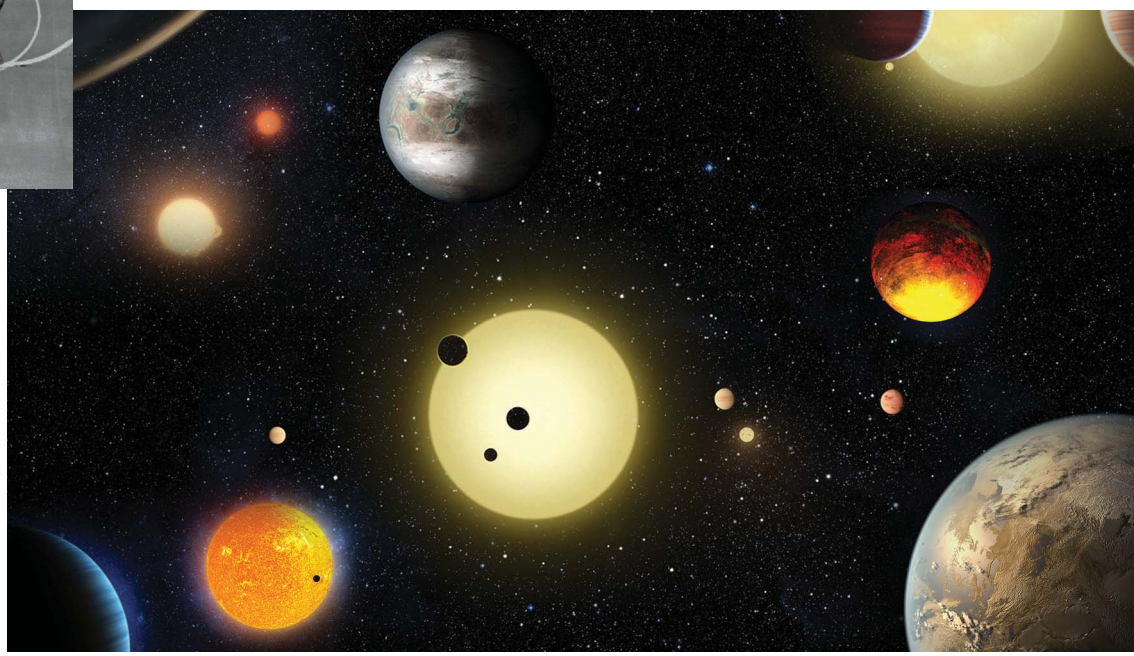
"Giving up the search for life definitely hurts us as a species since, in many ways, it means discarding the hope and aspiration for our species," says Kane. "It would result in the stagnation [of] our society, [which] has little to look forward to other than the next iteration of gaming console or streaming movie. The search for life is a uniting experience that constantly reminds us that our species can and should do amazing things that rise above the humdrum of day-to-day life."

"The search is progressing much faster now than it ever has in the past due to improvements in telescope and computing technology," says Sheikh. "I would say that by the end of my career (decades from now), we will be able to actually place meaningful upper limits on the prevalence of radio technology in the Milky Way. Until then, we just have to keep at it!"

"If we continue coming up empty, the public may grow skeptical or apathetic, but scientifically, the search remains valid and necessary," says Wael Farah, lead communication systems engineer at Cascade Space and a former SETI chair and project scientist for the Allen Telescope Array in northern California, which searches for signs of extraterrestrial life. But, he says, SETI represents an ongoing and rigorously scientific inquiry about our universe: "It's not simply a binary of 'we found them' or 'we didn't,' but a process of placing increasingly strict upper limits on how common technologically advanced civilizations might be. Every nondetection tells us something … that narrows the possibilities and refines our models. But we should absolutely keep searching. Even in silence, we're learning."



ABOVE: The so-called Fermi Paradox arises from a 1950 lunchtime query posed by physicist Enrico Fermi, pictured here circa that same year. The Fermi Paradox remains a much-debated aspect of the search for extraterrestrial intelligence. ATOMIC ENERGY COMMISSION. ARGONNE NATIONAL LABORATORY. OFFICE OF PUBLIC AFFAIRS.



RIGHT: We have discovered more than 6,000 planets in the Milky Way so far, some of which are depicted here in an artist's rendition. However, there are potentially hundreds of billions or more planets in our galaxy, leading to significant conclusions about how worlds — and life — evolve if we find no other civilizations like our own. NASA/W. STENZEL

Laurence Tognetti *is a USAF veteran, planetary geoscientist, and science writer.*

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING

Bright Jupiter shines just above thin clouds at left, below the stars Castor and Pollux, the heads of Gemini. This month offers many transits of the Galilean moons, sometimes together. ALAN DYER

MAY 2026

Galilean moons move in sync

Venus and Jupiter are the top evening features for your observing run after sunset in May. Jupiter also hosts a handful of exciting double transits — and double shadow transits — involving Europa and Ganymede. Saturn and Mars make a brief reappearance in the predawn sky, joined by a crescent Moon. So let's begin!

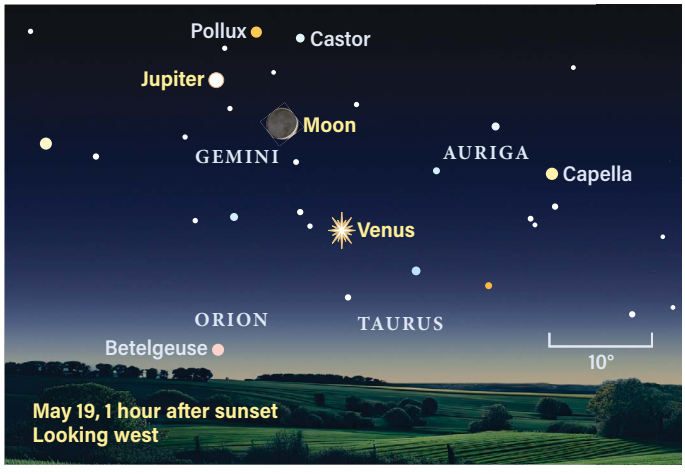
You'll find **Venus** shining brightly in the evening sky soon after sunset. On May 1 it stands 14° above the western horizon an hour after sunset and remains visible until about 10:30 P.M. local daylight time. By May 31 it remains above the horizon until about 11 P.M. A pair of amazing star clusters — the Pleiades (M45) and the Hyades — sit to the lower right and left of Venus, respectively. The latter is punctuated by the nearer bright star Aldebaran.

Venus starts at magnitude –3.9 and brightens to –4.0 during May as it moves across Taurus and into Gemini. It stands 6.5° due north of Aldebaran the night of the 2nd and lies between the horns of the Bull (Beta [β] and Zeta [ζ] Tauri) on the 13th.

On the 18th, a lovely crescent Moon stands 2° north of Venus. Watch them as the sky darkens and the earthshine on the Moon becomes more evident. Viewed from the Moon, Earth is an almost fully illuminated sphere, dazzlingly bright — enough to cast an ethereal light across the dark lunar surface.

The next evening (the 19th), Venus crosses into Gemini and stands some 20° west of Jupiter, while the crescent Moon has moved up to meet Jupiter, situated in the middle of Gemini about 7° from the bright planet. Watch for the rest of the month

Two worlds in the Twins



By May 19, Venus has entered Gemini, which also currently houses Jupiter. The two planets will continue to close in for the rest of the month. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

VENUS is positioned 6.5° north of Aldebaran in Taurus the evening of May 2.

as the gap between Venus and Jupiter closes, reaching about 8° on the 31st. The two planets are lining up for a fine conjunction in June.

Venus is an interesting object to view with a telescope, best done in twilight. Its brilliance makes the disk difficult to see against the harsh contrast of a black sky. In twilight, you'll easily see a gibbous phase all month, starting on May 1 as an 88-percent-lit disk spanning 12". The phase decreases to 80 percent lit by May 31, and the disk's diameter grows slightly to 13" as the planet's distance from us decreases.

Mercury becomes visible by the end of the month, quickly increasing its elongation from the Sun following superior conjunction on the 14th. On May 25, it is 6° above the western horizon 30 minutes after sunset, glowing at magnitude –1.1. Five days later, on the 30th, it is nearly 10° high 30 minutes after sunset, but has faded to magnitude –0.6. On the 31st, it sets an hour and a half

— *Continued on page 34*

RISING MOON | Libration all the way around

WHEN YOU WATCH someone roll their head all the way around, you won't see the back, but you will view more than just the front half. Our companion Luna appears to perform a similar maneuver, called libration, with a 27-day period, revealing a total of 59 percent of its face toward us, including a bit of the top, bottom, and sides. Binoculars are the best way to follow this motion, yet it is noticeable to the discerning eye. We've hit the timing just right this month, as the 29.5-day illumination cycle is in sync with the roll.

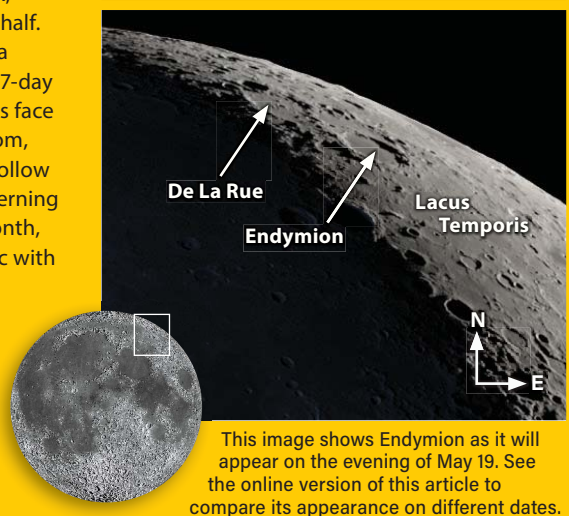
May opens at Full phase with Luna below the ecliptic, letting us see past the north pole. Nansen and Peary point the way to the outer rim of Rozhdestvenskiy. Note how close Tycho is to the bottom; Schickard's large, flat oval is to the southwest, and Oceanus Procellarum's lava goes right to the northwestern limb. Over the following nights, keep an eye on Mare Orientale, as dark Lacus Autumni and Veris roll into view as the nearer cordillera tilts down toward us.

Jumping to the pre-sunrise crescent on the 12th, Schickard has climbed well away from the limb. Returning to the evening crescent on the 19th, the mottled Mare Australe fills the southeast with dark and light lakes soon to roll away. See Mare Crisium and the flat-bottomed Endymion far to the northeast shift from near the limb to well inside it.

As we reach Full phase at month's end, the whole sequence now nearly repeats, but two days earlier, with each following month showing us less of the backside.

The Moon itself doesn't physically wobble — its apparent motion is due to our changing viewing angle.

Endymion

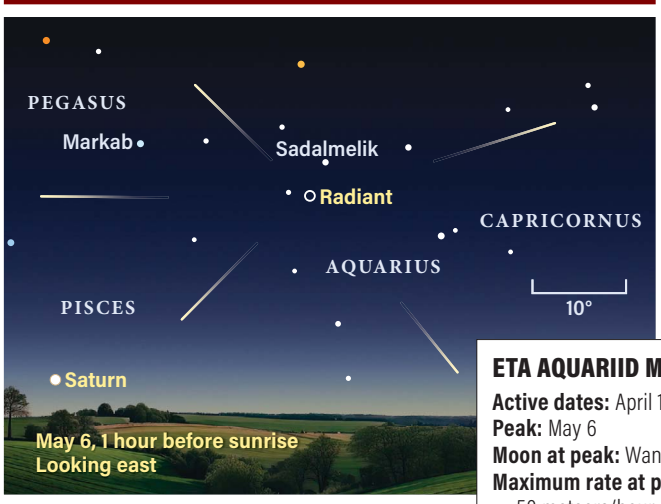


This image shows Endymion as it will appear on the evening of May 19. See the online version of this article to compare its appearance on different dates.

NASA SCIENTIFIC VISUALIZATION STUDIO. INSET: NASA/GSFC/ASU

METEOR WATCH | Faint but not forgotten

Eta Aquariid meteor shower



ETA AQUARIID METEORS

Active dates: April 19–May 28
Peak: May 6
Moon at peak: Waning gibbous
Maximum rate at peak: 50 meteors/hour

THIS MONTH'S ETA AQUARIID shower is active between April 19 and May 28, and peaks the morning of May 6. The waning gibbous Moon interferes strongly. On the night of maximum, the Moon lies in Sagittarius and stands in the southeastern sky as Aquarius rises. Moonlight strongly diminishes the number of meteors you will see.

The maximum zenithal hourly rate is 50 per hour on May 6 in a dark sky, but observed rates will be under a dozen per hour. The radiant rises around 2 A.M. local daylight time on the morning of maximum and reaches about 20° in altitude as twilight breaks. The hour before dawn is the best time to watch, with Earth heading directly into the stream, resulting in higher velocities of entry into our atmosphere. Although unfavorable this year, there's always strong interest in the shower due to its association with Halley's Comet. Halley's dusty debris, left over from hundreds of orbits, results in both this shower and the October Orionids each year.

Although the Moon will interfere, look east in the hour before dawn for bright Eta Aquariid meteors. Neptune is above the horizon but a challenge even with optical aid, so not shown here.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight May 1
11 P.M. May 15
10 P.M. May 31

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

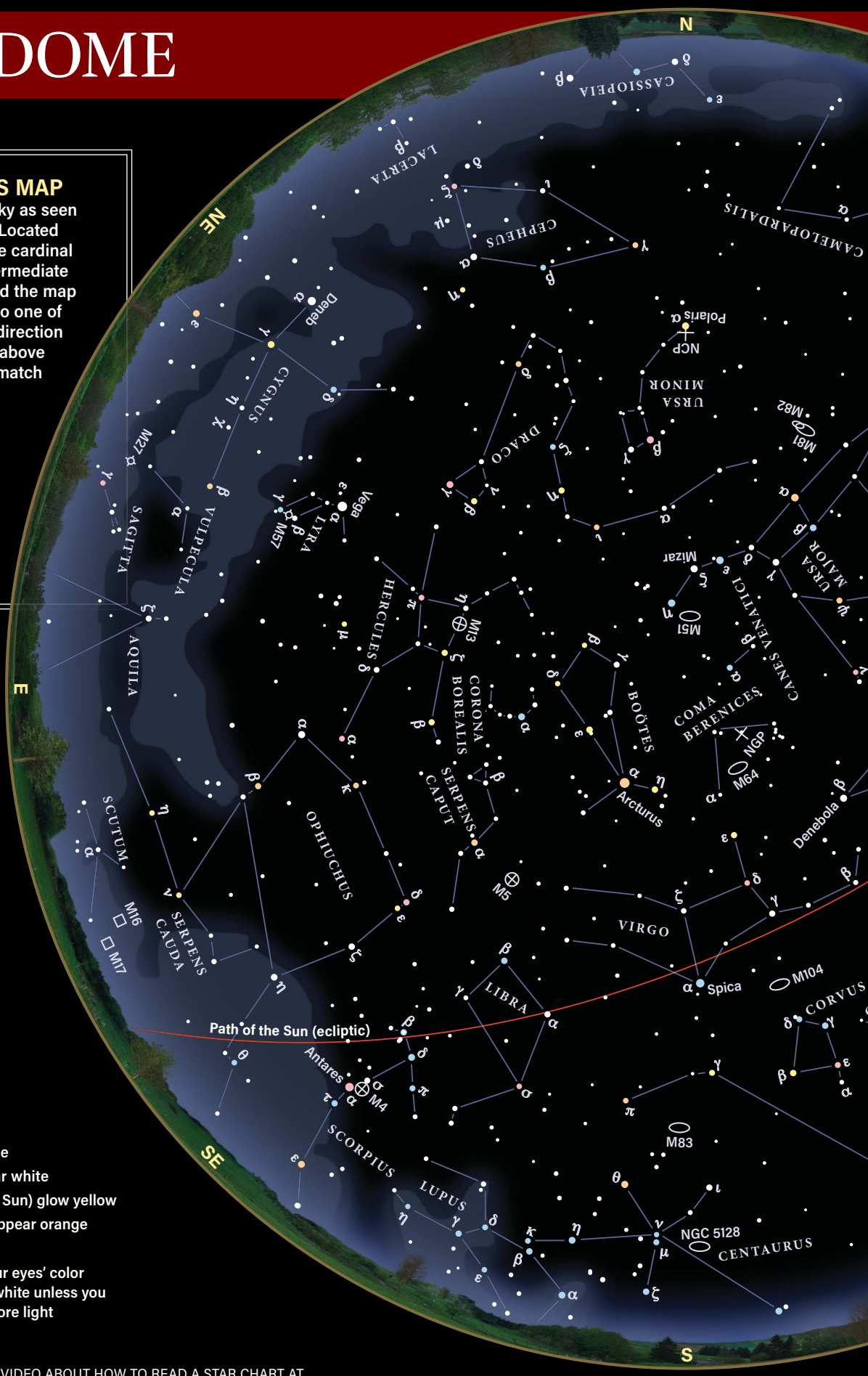
STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

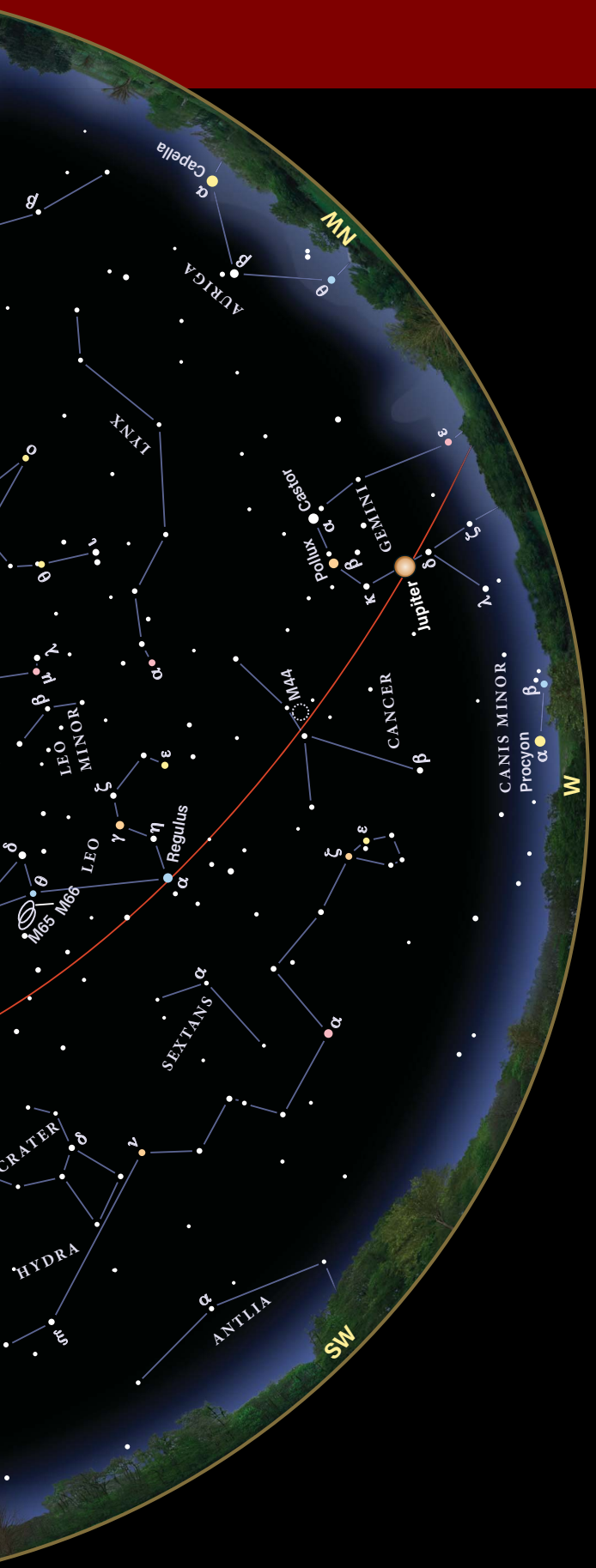
STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



MAY 2026

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 Full Moon occurs at 1:23 P.M. EDT

3 Venus passes 7° north of Aldebaran, 3 A.M. EDT

The Moon passes 0.5° south of Antares, 11 P.M. EDT

4 The Moon is at apogee (252,177 miles from Earth), 6:30 P.M. EDT

6 Eta Aquariid meteor shower peaks

8 Pluto is stationary, 7 A.M. EDT

9 Last Quarter Moon occurs at 5:10 P.M. EDT

13 The Moon passes 4° north of Neptune, 5 A.M. EDT

The Moon passes 6° north of Saturn, 6 P.M. EDT

14 Mercury is in superior conjunction, 10 A.M. EDT

The Moon passes 5° north of Mars, 9 P.M. EDT

Dwarf planet Ceres is in conjunction with the Sun, 11 P.M. EDT

16 New Moon occurs at 4:01 P.M. EDT

17 The Moon is at perigee (222,498 miles from Earth), 9:44 A.M. EDT

18 The Moon passes 3° north of Venus, 10 P.M. EDT

20 The Moon passes 3° north of Jupiter, 9 A.M. EDT

22 Uranus is in conjunction with the Sun, 10 A.M. EDT

23 The Moon passes 0.08° south of Regulus, 3 A.M. EDT

First Quarter Moon occurs at 7:11 A.M. EDT

31 Full Moon occurs at 4:45 A.M. EDT

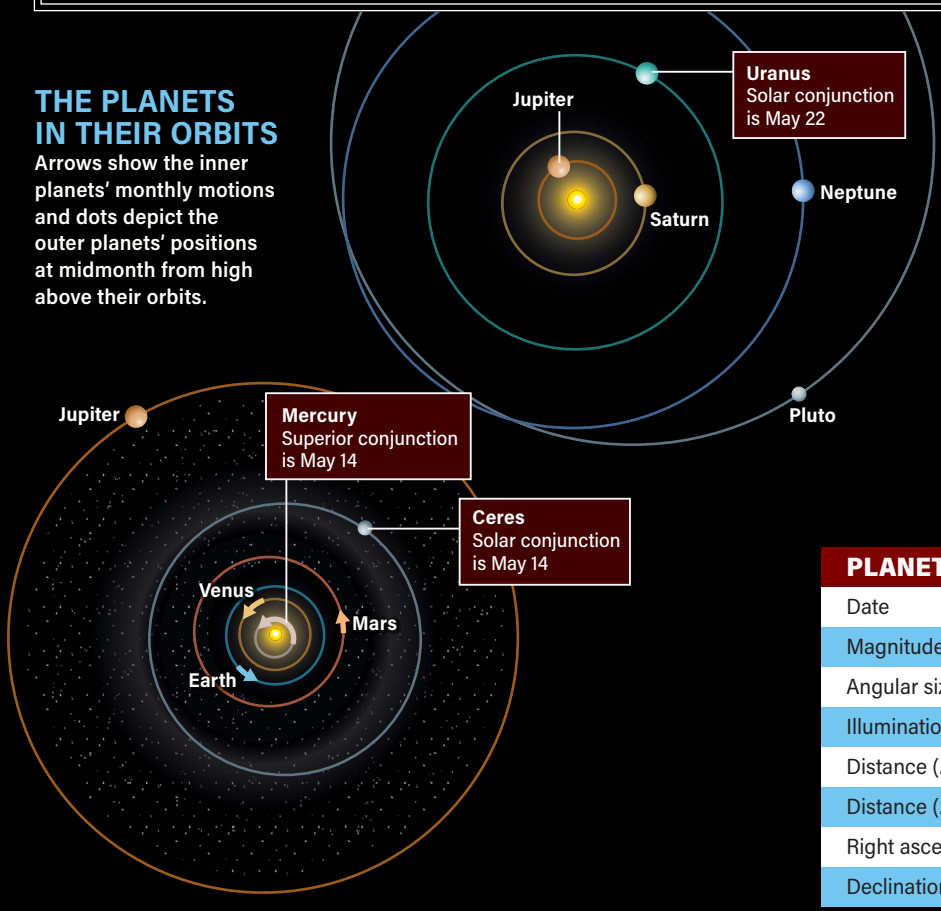
The Moon passes 0.4° south of Antares, 5 A.M. EDT

PATHS OF THE PLANETS

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

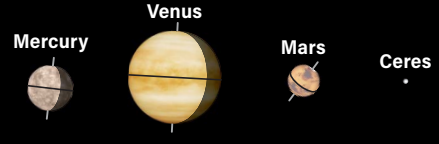
THE PLANETS IN THEIR ORBITS

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.



THE PLANETS IN THE SKY

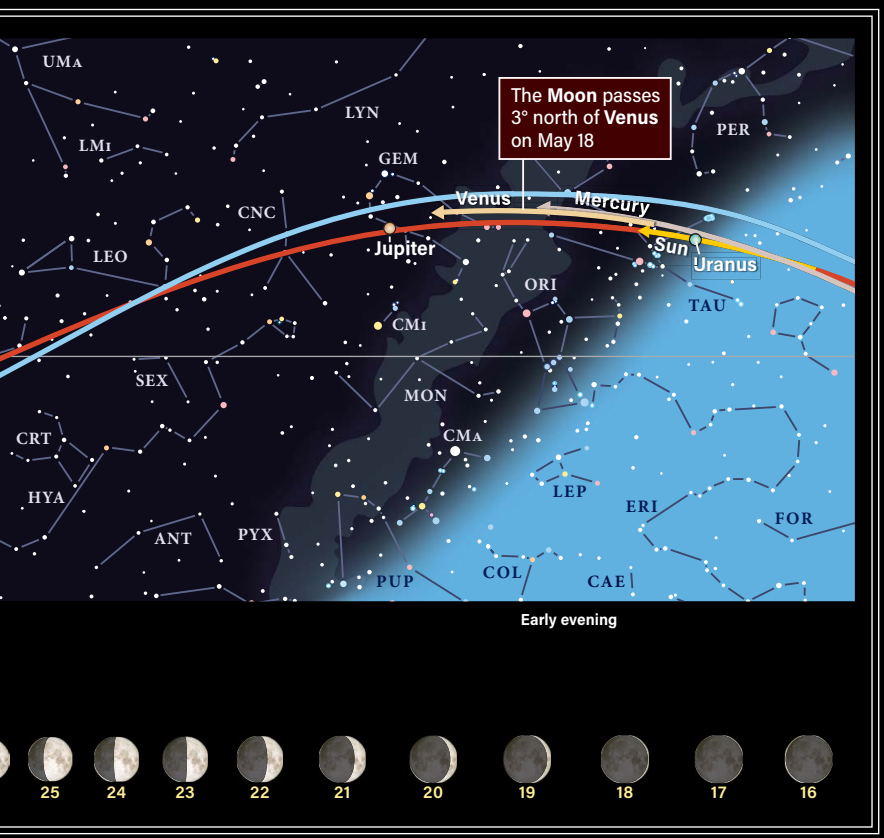
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



PLANETS	MERCURY	VENUS
Date	May 31	May 15
Magnitude	–0.6	–3.9
Angular size	6.0"	12.3"
Illumination	72%	84%
Distance (AU) from Earth	1.121	1.362
Distance (AU) from Sun	0.350	0.718
Right ascension (2000.0)	5h46.9m	5h37.1m
Declination (2000.0)	25°32'	24°48'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

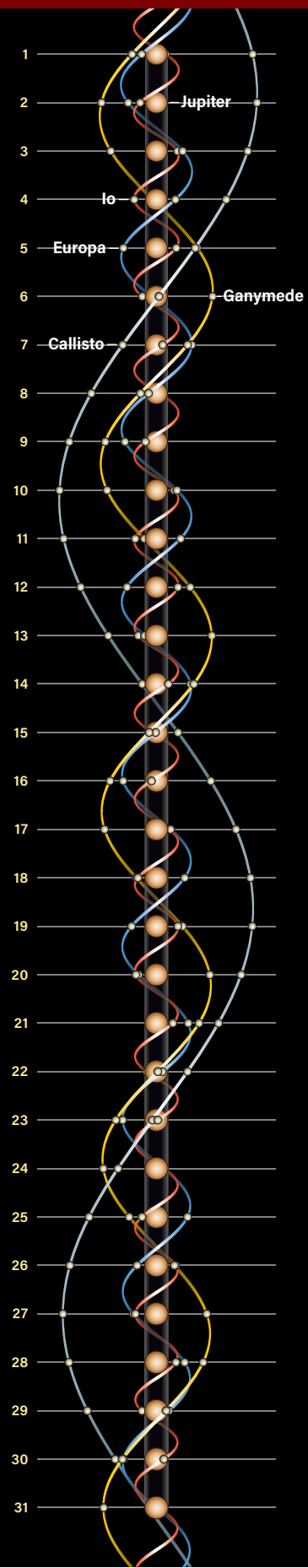
MAY 2026

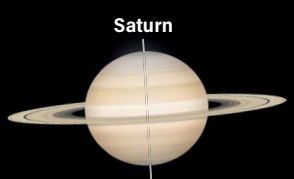


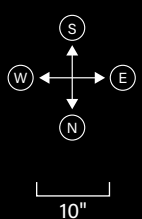
Early evening

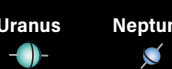
JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.





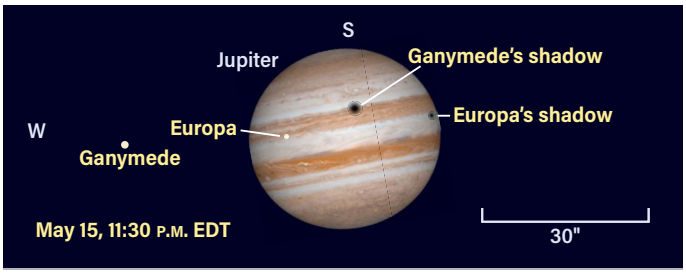




MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
May 15	May 15	May 15	May 15	May 15	May 15	May 15
1.2	8.7	–1.9	0.9	5.8	7.8	15.2
4.2"	0.4"	34.3"	16.3"	3.4"	2.2"	0.1"
97%	100%	99%	100%	100%	100%	100%
2.220	3.795	5.744	10.184	20.469	30.514	35.178
1.399	2.787	5.260	9.477	19.466	29.881	35.514
1h40.1m	3h29.6m	7h29.7m	0h41.3m	3h54.4m	0h14.2m	20h34.2m
9°33'	15°22'	22°14'	2°03'	20°08'	0°06'	–22°57'

 — Continued from page 29

Double shadows on show



Catch both Ganymede and Europa's shadows transiting Jupiter late on May 15, along with Europa itself. At this time, Io is occulted by Jupiter and Callisto lies farther east, outside this field of view.

after the Sun, and has dimmed another 0.1 magnitude. On that date, its disk spans 6" and appears 70 percent lit.

Returning to **Jupiter**, the gas giant remains visible until 1 A.M. local daylight time in early May and until nearly midnight by the end of May. It stands high in the western sky soon after sunset, visible as a magnitude –2.0 planet just to the lower left (southwest) of Gemini's twin stars, Castor and Pollux. It fades (barely noticeably) to magnitude –1.9 by midmonth. On May 31, Jupiter stands just over 6° south-southwest of Pollux. On May 19 and 20, a crescent Moon stands within 8° west and east of Jupiter, respectively, drawing attention to the giant planet.

The visibility of Jupiter is narrowing, and to capture features on its disk with a telescope requires good seeing while the planet is still at a decent altitude. Early evening in deep twilight is a good place to start. You'll notice a wealth of detail on its cloud tops. Two dark belts span the equator, with more subtle shading and features on other parts of the globe. During May, Jupiter shrinks from 35" to 33".

A fine series of double shadow transits involving Europa and Ganymede occurs this month. But first, there's a nice transit of Callisto as two other moons are occulted. Watch May 6 as Callisto's transit begins at Jupiter's eastern limb at 10:33 P.M. EDT (in twilight for the Mountain time zone). Notice Europa approaching the western limb — about one hour later (11:36 P.M. EDT), Europa disappears in an occultation, hidden by Jupiter's disk. Next, Io (also approaching from the west) is occulted at 11:35 P.M. PDT, followed by Callisto's exit from transit at 11:41 P.M. PDT, best seen from this time zone.

The following night you can watch Io transit Jupiter, an event that takes less time due to its faster orbital period. The transit begins May 7 at 11:48 P.M. EDT. Just over an hour later, at 11:56 P.M. CDT (note the time zone change), Io's shadow appears at the eastern limb. Io then leaves the disk at 12:04 A.M. MDT, with Jupiter some 7° high from this region. Pacific Coast observers will see the egress clearly, followed about an hour later by the shadow's egress as well.

A double shadow transit occurs May 15/16, as Europa and Ganymede's shadows cross the jovian disk overnight. As twilight falls on May 15 across the Central time zone, Europa is transiting as Ganymede's shadow appears at the eastern limb (at 9:58 P.M. EDT). Ganymede itself stands west of the planet. Europa's shadow appears on the eastern limb of Jupiter at 11:20 P.M. EDT. Europa exits the disk at 11:03 P.M. CDT (with Jupiter

WHEN TO VIEW THE PLANETS

EVENING SKY
Mercury (west)
Venus (west)
Jupiter (west)

MIDNIGHT
Jupiter (west)

MORNING SKY
Mars (east)
Saturn (east)
Neptune (east)

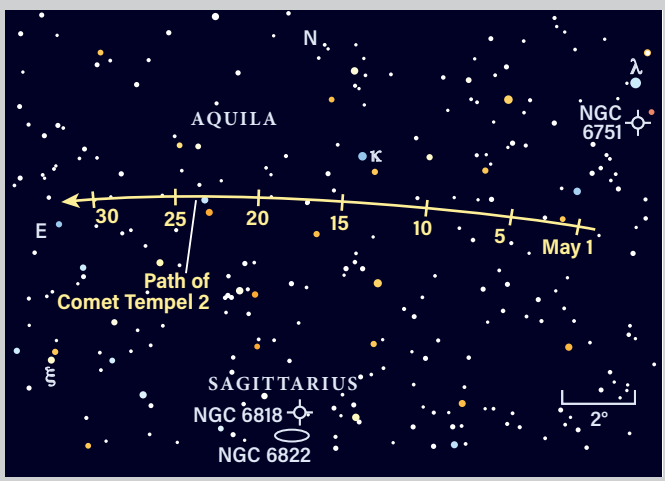
COMET SEARCH | Inbound for opposition

RELIABLE COMET 10P/TEMPEL (also called Tempel 2) is back, here to keep us company the whole summer through. It's a decent telescopic comet brightening past 9th magnitude, destined to hit the top three of its apparitions since discovery in 1873. May is the month to stay up late as our programming switches from galaxy fields to the core of the Milky Way in the south. By 1 A.M. local daylight time, our target is more than 10° high, and starting on May 8/9, the session-ending Moon rises closer and closer to dawn.

Our lookalike object is magnitude 9.2 globular cluster NGC 6638 near the lid of the Sagittarius Teapot asterism. From a dark sky, these nonstellar fuzzies can be picked up through a 4-inch scope, but powers of 150x are better handled with 6- to 8-inch optics. Tempel 2 should be lopsided, sharper where the solar wind pushes back the emitted dust, different from the rounder globular. Is the light falloff from the comet's bright core better simulated by the elliptical galaxy M87? What about the texture?

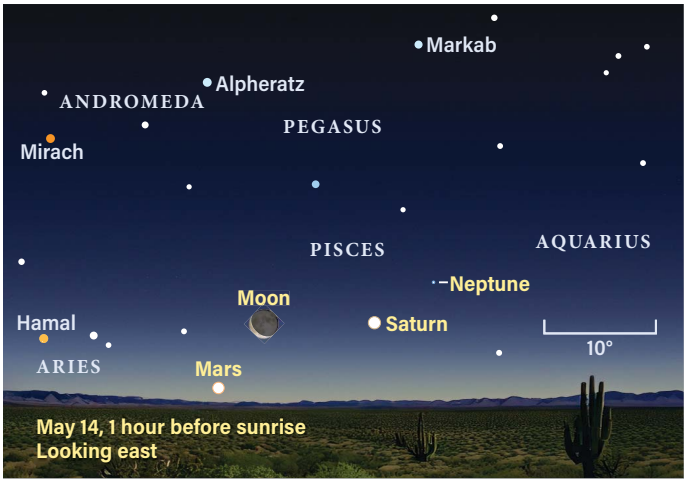
Wilhelm Tempel was a successful visual observer, nabbing 21 comets and 5 asteroids during the period when photography was barely able to record the Great Orion Nebula.

Comet 10P/Tempel



Comet Tempel 2 is passing through the rich star fields of southern Aquila this month. The Sagittarius Teapot and NGC 6638 lie southwest of the region shown here, while northwestern Capricornus is at lower left.

Red Planet returns



By mid-May, Mars has reappeared, visible briefly in the early-morning sky. Try on the 14th, with a delicate crescent Moon nearby. Neptune will require optical aid, and is best seen earlier in the morning.

very low along the East Coast), leaving the two shadows alone on the cloud tops. Ganymede's shadow is clearly larger and slower moving. Watch over the next hour to see Europa's shadow gaining on Ganymede's, though it won't catch up — Ganymede's shadow leaves at 11:26 P.M. MDT, visible largely in the western half of the U.S.

Seven days later, a similar event occurs. Europa and Ganymede cross the disk the evening of May 22; also make note of Io west of the planet. Ganymede's transit begins at 9:57 P.M. EDT and Europa follows 2 hours later. Io approaches the western limb and enters occultation at 11:02 P.M. MDT (note the time change), just as Ganymede approaches the same limb, exiting about 20 minutes later. Europa then sits in the center of Jupiter's disk.

What's remarkable about this double transit is that the shadows arrive at nearly the same time on the eastern limb. Watch this happen about 10:55 P.M. PDT, best seen from the western Pacific time zone, as Jupiter is only 9° high. Which shadow do you see first? Ganymede's is larger, but Europa's shadow appears two minutes earlier, moving faster so that it quickly springs ahead of Ganymede's. Observers in Alaska and Hawaii will have the best views of the majority of the double shadow transit.

By the end of May, Jupiter sets half an hour before midnight. Another double transit of Europa and Ganymede occurs on May 29 but it's only visible in Alaska and Hawaii (the latter of which has the best view).

Saturn becomes a bit easier to spot in May, notwithstanding the low inclination of the ecliptic to the predawn horizon. By May 13, it stands 7° high in the eastern sky an hour before sunrise. It'll be easy to spot then because a waning crescent Moon rises about half an hour before Saturn (which rises shortly after 4 A.M. local daylight time), with Saturn 6° below the crescent.

The following morning, look for the Moon again, then scan 7° to its lower left (east) for **Mars**, shining at magnitude 1.3. By May 15, the Moon is almost gone (one day away from New), but it does rise a few minutes before Mars. The planet is now southwest (to the right) of the Moon. Both are a similar altitude above the horizon, rising about an hour before sunrise.

Neptune may be easier to spot in late May as its elongation from the Sun increases. You'll find it 8° west of Saturn on the 31st, standing 10° high in the eastern sky two hours before sunrise.

Uranus reaches conjunction with the Sun May 22 and although it is briefly above the western horizon on early May evenings, it isn't readily visible this month.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

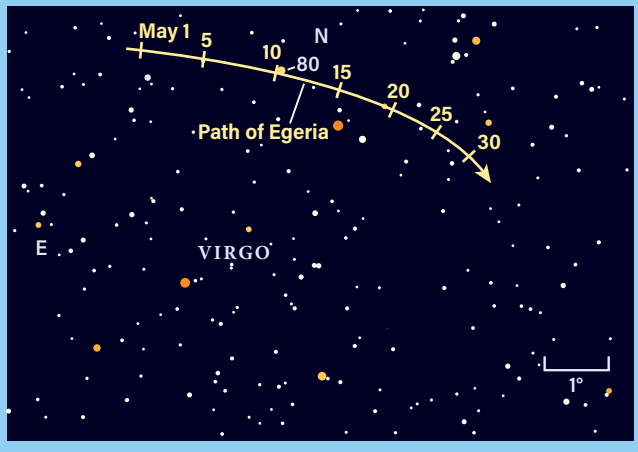
LOCATING ASTEROIDS | A practiced jump

THERE ARE SEVERAL beacons in the evening sky to help orient ourselves in space. Our lighthouse this month is Spica (Alpha [α] Virginis), a third of the way up in the southern sky as darkness sets in. Shift one finder field or outer Telrad ring north to find a wide stick-figure of a lawnmower. The handle, magnitude 5.7 80 Vir, lies right on the path of main-belt asteroid 13 Egeria.

A 4-inch scope from the suburbs is needed to pull the 10th-magnitude dot confidently into view. Star-hopping here is straightforward. The background is not overcrowded with suns from the galactic hub, while the variety of magnitudes and shapes lets us lock onto pattern after pattern while shifting the telescope. The best dates for seeing Egeria move in a three-hour session are May 5, 6, 11, 19, and 24. Make sure your comparison sketch has at least two field stars to set the sky's orientation.

Annibale de Gasparis was on a discovery roll, having just picked up 10 Hygiea and 11 Parthenope. In November of 1850, asteroid No. 13 floated into his eyepiece at magnitude 10.1, with no matching dot on his star charts. With a reflectivity of about 8 percent and diameter of 125 miles, Egeria's steep 16° inclination to the ecliptic eliminates any interest for a space mission. It's all ours to watch.

By the bright light



Egeria is a 6° hop from bright Spica (south of this field) in May.

The science and

The physics behind the northern lights is just as colorful as their mythology. BY RAYMOND SHUBINSKI

THE SHIMMERING CURTAINS of the northern and southern lights — aurora borealis and aurora australis, respectively — loom large in our imaginations. These shifting apparitions provide a cosmic connection not only to beauty and mystery, but also to our physical world.

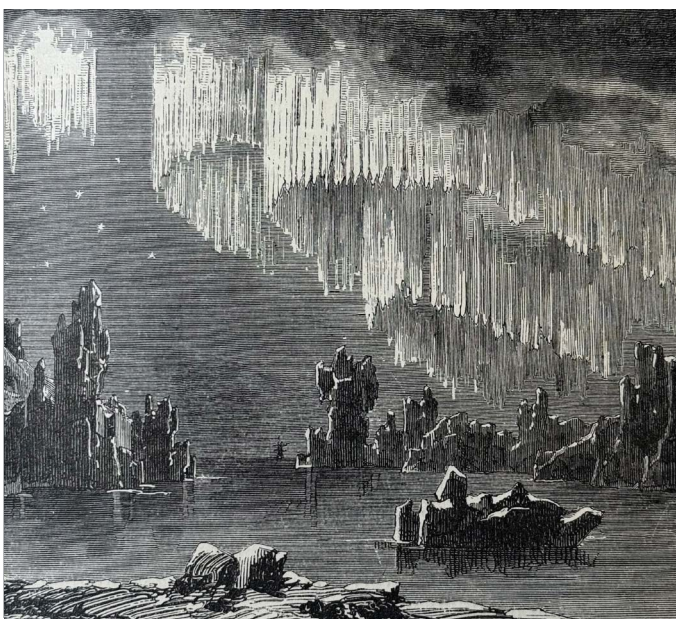
Unlike the rhythms of the Sun, Moon, and stars, aurorae appear to be capricious and elusive. As the sky darkens, a glow may be seen in the sky that grows as the night progresses, eventually becoming shimmering curtains of red, green, and perhaps blue, only to fade away. While modern science explains the phenomenon and tour companies even offer trips to remote locations for those who long to see the lights, it's hard to imagine the effect they had on those watching the skies long ago.

Early thoughts

Aurorae are seen in Earth's northern and southern latitudes, and fascination with them is ingrained in many cultures. The Sámi, Indigenous people of Lapland, believed the dancing lights to be the souls of their ancestors, and showed respect by never whistling or pointing at them. The Māori of New Zealand traditionally imagined the aurora as campfires of their departed ancestors, while Aboriginals in Australia feared raging celestial brush fires and saw in them omens of future catastrophes.

The 3,000-year-old Chinese *Bamboo Annals* may contain the oldest reference to the aurora, although some scholars believe Cro-Magnons drew them on rocks and cave walls. Ancient observers such as the Roman general Pliny the Elder, who died during the eruption of Mount Vesuvius, wrote about beams of light and red flames descending from the sky. Aristotle expounded on this phenomenon in his 340 B.C.E. book *Meteorology*. And references in the Old Testament to "a great stormwind [that] came from the North, a large cloud with flashing fire, a bright glow all around it" may be sightings of these lights.

The northern lights received their current moniker in 1619. Three comets had dazzled Europe the year before and had pulled Galileo into a controversy about their nature. In his 1619 pamphlet, *Discorso delle Comete*, he wrote that comets were atmospheric phenomena like the northern lights. Galileo also speculated that the shimmering lights were caused by sunlight reflected in the atmosphere. He was wrong about the nature of comets, but right about the atmospheric nature of the lights. In his pamphlet, he coined the term *aurora borealis*, which combines the names Aurora, the Roman goddess of the dawn, and Boreas, the Greek god of the cold north wind.



ABOVE: This six-image panorama of colorful aurora from seaside of the Arctic Ocean in Teriberka, Murmansk, Russia, was shot Jan. 7, 2019, through a Canon 6D DSLR with a Tamron 15–30mm lens set at 15mm and f/2.8. Each exposure was 10 seconds long. JEFF DAI

LEFT: This illustration, titled "An aurora borealis over the Polar Sea," comes from the author's copy of the 1873 edition of Camille Flammarion's *The Atmosphere*. RAYMOND SHUBINSKI

lore of aurorae

About 150 years later, Benjamin Franklin, who was all about things electric, suggested that the aurora was caused when electric charge was drawn to the north and south magnetic poles and released curtains of light when the charge became too great. This idea stuck well into the 19th century.

In 1851, Edward Sabine, an English military officer and polar explorer, made a fundamental discovery about aurorae. He learned about the work of the German amateur astronomer, Samuel Schwabe, who had recorded sunspots for 30 years. These extended observations revealed the cyclic nature of sunspots. Sabine had observed the aurora many times during his polar expeditions. He compared his records of auroral occurrences with Schwabe's observations and saw a correlation between the two. The astronomical community dismissed Sabine's idea as being without merit. How could the Sun, 93 million miles away, cause an atmospheric phenomenon?

Sabine would not be vindicated until the 20th century. But tentative connections between sunspots and aurorae came less than a decade later.

On the night of Aug. 28, 1859, telegraph offices across America and Europe began failing. The wires leading to the telegraph keys got so hot that the contacts on the equipment nearly melted. One

unfortunate operator came too close to a ground wire and received a severe electric shock to his forehead. Technicians disconnected the battery systems, but telegraphists could send messages because currents were still running through the lines. After the system was restored, reports began coming in of incredibly bright aurorae seen across America, Europe, Australia, and even Cuba.

Just a few days later, on Sept. 1, amateur astronomer Richard Carrington reported a monstrously big sunspot. Carrington sent a report to the Royal Astronomical Society describing his astounding observations. He even suggested that particles were being blown from these bright spots. A fellow amateur, Richard Hodgson, also saw the sunspot and the brilliant explosions, confirming the event. Carrington and Hodgson were the first humans to directly witness solar flares — part of an outburst that enveloped Earth in a week-long geomagnetic storm now known as the Carrington Event. These observations provided the first real links of the Sun-Earth-aurora connection.

The color you see depends on the gas that is being excited. Aurorae can appear green, red, blue, and even a little purple or pink.

Modern science

Scientific discovery is built on previous successes and mistakes. Carrington speculated that the bright flashes he saw had sent particles flying toward Earth, but the idea that the Sun was spewing a particle "rain" was hard to believe. Two decades later, in 1880, the French physicist Henri Becquerel made a strong case that aurorae were caused by these particles.

In 1957, astrophysicist Eugene Parker theorized that the Sun produces a constant output of these particles. The idea was dismissed by some as nonsense. Early in the space race, however, the existence of the solar wind was verified by the Soviet Luna spacecraft. The cosmic connection was finally complete.

We now understand that the Sun is a churning mass of plasma, flowing from deep within its interior to its surface. Also, the Sun's polar regions rotate more slowly than the equatorial areas, twisting its magnetic fields and plasma. When the plasma erupts into the photosphere (the visible surface) we see sunspots. They look dark because they're cooler than the surrounding area. These spots crackle with magnetic energy and release solar flares, which spew tremendous amounts of charged particles that cause aurorae when they impact Earth's atmosphere. The smallest A-class flares are powerful, but X-class flares are capable of creating Carrington Event-level disruptions.

Light show

Earth's atmospheric envelope is protected by a magnetic forcefield called the magnetosphere. The solar wind is made of protons and electrons stripped from atoms in the Sun's corona. Those charged particles are trapped by the magnetosphere, where they build up energy. The impact of a powerful coronal mass ejection can release this pent-up energy. The charged particles then penetrate the magnetosphere and are funneled into our upper atmosphere, where the magic begins.

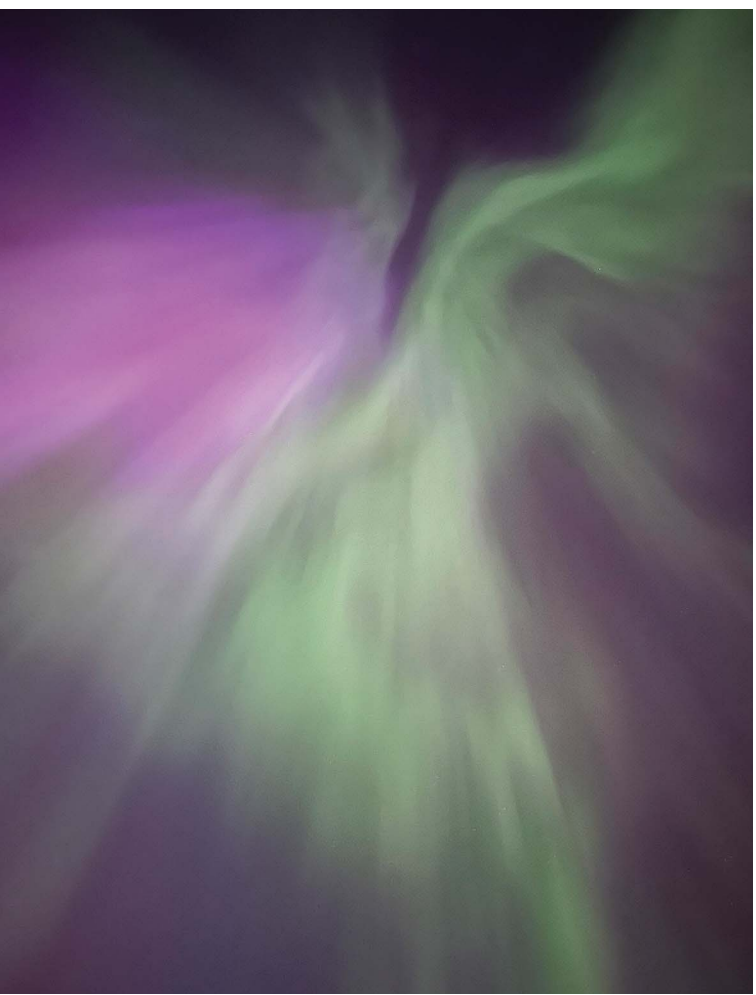
Electrons that spin around the nucleus of an atom have specific energies. When the fast-moving solar particles impact oxygen and nitrogen molecules, their electrons get an extra kick of energy, moving them to a higher level.

When that energy boost is released, light is emitted. Neon lights work on the same principle.

Just like with a neon light, the color you see depends on the gas that is being excited. Aurorae can appear green, red, blue, and even a little purple or pink. When oxygen is excited, it produces a vivid green or an intense red. Nitrogen glows a beautiful blue during this process, along with shades of purple and pink. All of this happens between 60 and 120 miles (95 to 195 kilometers) above Earth's surface.

LEFT: French astronomy popularizer Camille Flammarion wrote a lot about aurorae in his 1873 book *The Atmosphere*. This chromolithograph shows a rayed aurora seen from Paris on May 13, 1869. RAYMOND SHUBINSKI

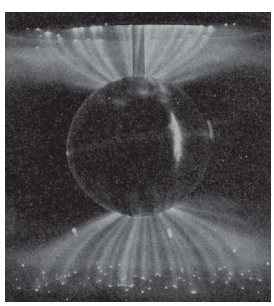
BELOW: The author took this picture May 10, 2024, from St. Joseph, Michigan, with his iPhone 13. RAYMOND SHUBINSKI



Aurorae appear more frequently in high Arctic and Antarctic areas in what's called the auroral oval or zone. This zone is roughly centered along the Arctic and Antarctic circles near 67° north and south latitudes.

ELECTRICITY FROM THE SKY

KRISTIAN BIRKELAND provided yet another link in the connection between the Sun and Earth's atmosphere. Something of the Nikola Tesla of Norwegian physics, he made detailed observations of aurorae from Arctic stations in the late 19th century. His studies led him to the idea that polar electrical currents, now called electrojets, drive and shape aurorae. To demonstrate this, he even built equipment that could create miniature aurorae in the laboratory. Birkeland's polar electric currents were dismissed as fantasy for years, but were eventually understood to play a key role in auroral structure and how disturbances in our planet's magnetic field cause electromagnetic phenomena at Earth's surface during geomagnetic storms. In March of 2025, NASA launched the Electrojet Zeeman Imaging Explorer (EZIE) to study these auroral electrojets.



Birkeland created these currents, which resemble aurorae, in his laboratory in 1903, and included them in his two-volume *The Norwegian Aurora Polaris Expedition*. KRISTIAN BIRKELAND/WIKIMEDIA COMMONS

The corona aurora, the most dramatic of the forms, is only seen if the observer is under the oval. This aurora encircles the watcher and spirals away from the zenith. Other types of displays include curtains, pillars, rays, arcs, bands, and even dunes. Recently, STEVEs (Strong Thermal Emission Velocity Enhancement) have been added along with proton pancakes. STEVEs are purple and green streaks that often appear with auroral displays, while pancakes are flat red blobs caused by excited protons rather than electrons.

As the Sun reaches the peak of solar activity and sunspots, called the solar maximum (or solar max), the chances of seeing aurorae dramatically increase. There's also an aurora season around the equinoxes caused by the Russell-McPherron effect, which provides a "magnetic" connection between Earth and the Sun. Most of the year, the magnetic poles of these two celestial bodies are misaligned. At the equinoxes, our magnetic field comes into alignment with the solar wind, creating more aurorae.

You may love the Finnish stories of firefoxes brushing their tails against mountains and making the sky glow, or Inuit ancestors lighting the sky with a celestial ball game. Perhaps you're even saving for a trip that will let you stand under an auroral arc in Iceland. Whether you're a scientist or a casual observer, the aurora will always have the power to inspire wonder and connect us to the cosmos in ways few celestial events can.

Contributing Editor **Raymond Shubinski** *saw a corona aurora during the solar max of 1968. He's still waiting to see it again.*

Swing your scope to SPRING'S STAR CLUSTERS

This season may be known for galaxies, but some impressive clusters are also within view.

BY PHIL HARRINGTON

AS WINTER'S BRILLIANT STARS slip toward the western horizon and the constellations of spring climb higher, Northern Hemisphere observers discover a quieter but richly rewarding sky. Spring is celebrated for its galaxies, yet our own Milky Way offers an equally compelling bounty of open and globular clusters. From youthful, loosely packed groups that still sparkle along the fading winter Milky Way to ancient spheres that hover near the galactic halo, from the feet of Gemini to the long winding tail of Hydra, these stellar gatherings invite exploration.

ALL PHOTOS: PHIL HARRINGTON, UNLESS OTHERWISE NOTED

Open clusters

Let's begin our journey in Gemini, a "bridge" constellation: While normally associated with the winter sky, the twin brothers hang in the west well into spring after their frosty compatriots have set.

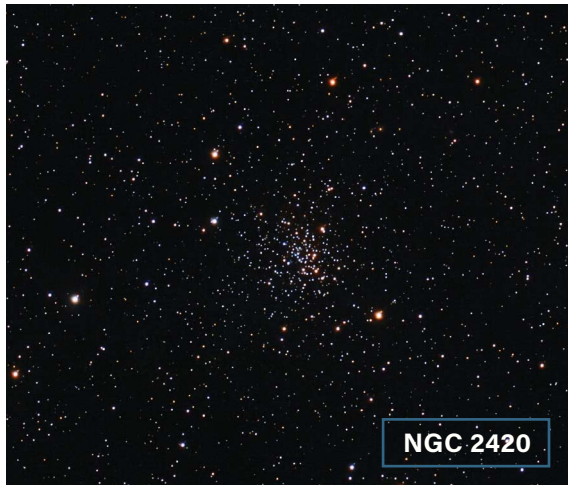
We find **M35**, a magnificent open cluster, lying near the foot of Pollux. M35 was discovered by Swiss astronomer Philippe Loys de Chéseaux around 1745. It lies about 3,000 light-years away and is nearly 25 light-years across. More than 400 stars shine within its bounds, with many blue-white suns hinting at the cluster's youthful age of about 150 million years. Through a 3- or 4-inch telescope, M35's stars sparkle like diamonds on dark velvet, with a dense core and delicate streamers radiating outward.

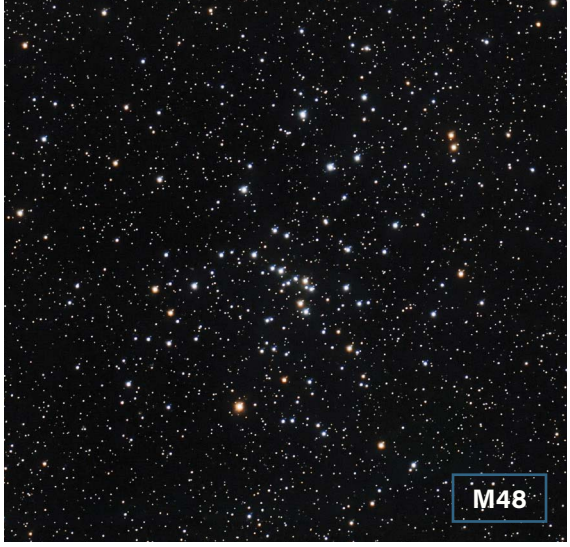
Nearby lurks **NGC 2158**, a compact and fainter open cluster located about 11,000 light-years away. This ancient cluster is more than a billion years old and contains roughly 10,000 stars, making it one of the richest and oldest open clusters visible in our galaxy. Because of its great distance and advanced age, its stars appear noticeably dimmer than those in M35 and glow with a soft golden hue, the hallmark of aging suns. Through 6-inch and larger telescopes, NGC 2158's faint, densely packed stars form a beautiful contrast to the bright, youthful glitter of M35. Try 150x or more for the best results.

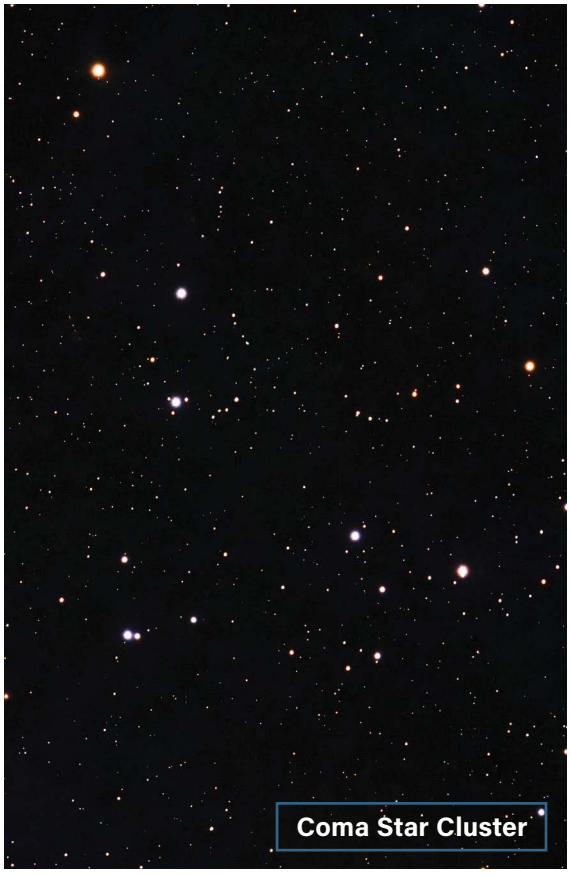
Gemini also holds another, less-well-observed open cluster. **NGC 2420** is a rich and compact gathering of stars that rewards patient observers on clear early spring nights. Discovered by William Herschel in 1783, this 8th-magnitude cluster lies about 10,000 light-years away on the outer edge of the Milky Way's disk. It contains more than 500 stars within a span of about 30 light-years and appears just over 6′ across in our sky. Through small telescopes, NGC 2420 looks like a faint, grainy patch that begins to break into tiny points with increasing aperture and magnification. Larger instruments show a dense, wedge-shaped swarm of yellowish stars, a reflection of the cluster's advanced age of about 2 billion years. To find it, sweep about 4° east of Delta (δ) Geminorum using low power.

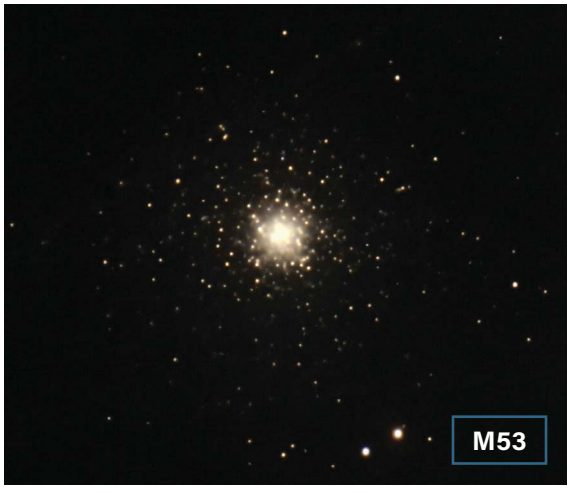
Moving eastward along the ecliptic, we come to Cancer the Crab. Cancer is well known as home to **M44**, commonly called the Beehive Cluster. M44 is among the most prominent open clusters in the northern sky and brings fame to a faint constellation that is only visible under dark skies. Spanning an area roughly three times the apparent diameter of the Moon, M44 is best appreciated through binoculars or a low-power telescope.

ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA









Higher magnifications fragment its beauty, losing the clustering effect.

With 80 or so suns visible through modest optics, the cluster does indeed suggest a busy swarm of bees. Careful inspection reveals several small stellar groupings within the cluster that hint at patterns, including a V-shaped pattern across its center that reminds me of a heart. Stargazers in antiquity knew it as Praesepe, Latin for "manger," and noted its haze even before telescopes existed.

While M44 brings observers to the Crab, many move on without viewing a second striking open cluster within the constellation. **M67** is a rich gathering about 2,700 light-years away and is one of the oldest known open clusters in the Milky Way. While M44 is believed to be a spry 830 million years old, elderly M67 is far older at about 4 billion years. That rivals the Sun in age. Through binoculars it appears as a small, hazy glow, while backyard telescopes resolve dozens of stars. Spanning about half a degree, M67 shows best at 50x to 75x. Look carefully — can you also spot a winding line of stars that bends into a hooklike curve? This pattern has inspired the nickname the King Cobra Cluster. M67 is also called the Golden Eye Cluster because many of its brighter stars shine with a warm yellow or golden hue.

Spring skies showcase Hydra, the sky's largest constellation, also linking winter stars to the summer Milky Way. It stretches more than 100° and contains mostly faint galaxies. But it also hides an often-overlooked open cluster. **M48** is sometimes referred to as the Lost and Found Cluster because of its history. Charles Messier discovered it in 1771 but mistakenly recorded its position 5° too far north. His error left M48 "lost" until 1934, when German astronomer Oswalt Thomas identified it as the same cluster as NGC 2548. Since M48 spans about half a degree of sky, a low-power eyepiece works best. Centered, it appears as a bright cluster of more than 50 stars, highlighted by lines and arcs. Eight central stars form a capital A, while outliers give the cluster an overall arrowhead-like shape.

Our next destination, Coma Berenices, is a faint constellation defined by just three modest naked-eye stars forming a right triangle. Dark skies, however, also show a faint misty glow west of those stars. That glow is the **Coma Star Cluster** (Melotte 111), which lies about 280 light-years away. More than 270 stars belong to the cluster, with roughly 40 shining brighter than 10th magnitude. Those stars span 5° of sky (more to giant scopes), making this an ideal target for binoculars. Through binoculars, the cluster's brightest stars align in arcs and lines resembling a V-shaped gaggle of flying geese. The brightest members include 12, 13, 14, 16, and 21 Comae Berenices. Several pairs stand out, notably 17 Com with its 7th-magnitude companion.

For a real observing challenge, look just 4° from Polaris (Alpha [α] Ursae Minoris) toward Cepheus to find **NGC 188**, often called the Polarissima Cluster. Discovered by John Herschel in 1831 near the 4th-magnitude star SAO 181, this faint open cluster appears as a dim, round glow through a 4- to 6-inch telescope, with tiny points scattered across it. Larger scopes reveal dozens of faint suns loosely arranged, yet the group remains a subtle, grainy patch. Its allure lies in its advanced age, approximately 6.4 billion years old. Most open clusters scatter quickly, but NGC 188 has survived thanks to its location above the Milky Way's disk, where the galaxy's disruptive gravitational pull is weaker.

Globular clusters

There are also several globular clusters scattered throughout

M67 IS A RICH GATHERING ABOUT 2,700 LIGHT-YEARS AWAY AND IS ONE OF THE OLDEST KNOWN OPEN CLUSTERS IN THE MILKY WAY.

our spring sky. We'll start with **M3** in Canes Venatici, the finest globular cluster of the season. Discovered by Charles Messier in 1764, M3 shines as a dense ball of half a million stars 34,000 light-years away.

M3 is a spring showpiece that never disappoints, no matter the instrument. Even a 3-inch telescope shows a bright, hazy glow concentrated toward the core. With 4 inches of aperture, the haze begins to break into hundreds of tiny points surrounding the compact nucleus. An 8-inch or larger scope fully resolves the cluster, revealing stars spread across its face. Some appear to line up in curious chains, a pattern first noted by William Herschel, although these are only chance alignments.

Discovered in 1775 by Johann Bode, **M53** lies in nearby Coma Berenices but will prove tougher to find than M3. Like M3, M53 seems out of place in the spring sky. In a region dominated by other galaxies, it stands out as one of this constellation's few Milky Way deep-sky objects. And at its estimated distance of 58,000 light-years, M53 is one of the most remote globular clusters associated with our galaxy, lying on the verge of intergalactic space.

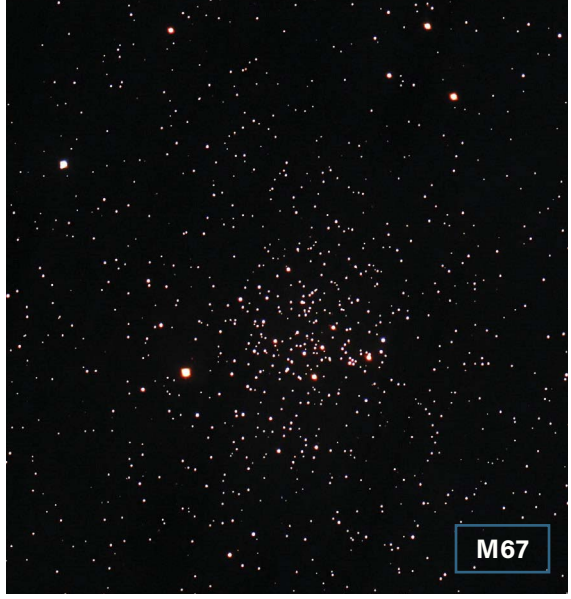
That extreme distance makes M53 tough to resolve into stars. A 4- to 6-inch scope reveals a compact, bright core with a slightly grainy outer halo hinting at unresolved stars. In 11- to 16-inch instruments, M53 becomes a dazzling swarm of faint suns, its dense core surrounded by a gradually thinning field of dim points that spill outward in all directions.

Swinging south to Corvus the Crow, we find **M68**. Discovered by Charles Messier in 1780, this globular is about 33,600 light-years away and 110 light-years across. Despite its brightness, it often goes unnoticed, tucked low in the sky and far from easy star-hopping paths. Even moderately large telescopes struggle to resolve its loosely packed stars, though 11-inch and larger scopes reveal a rich scatter of faint points surrounding a brighter, mottled core. Interestingly, M68 may not be a native Milky Way cluster. Its motion and chemistry suggest it was once part of a small galaxy absorbed by our own billions of years ago. Now a cosmic refugee orbiting the galaxy, M68 offers observers not just a beautiful target but a glimpse into the Milky Way's dynamic, cannibalistic past.

Galaxies aren't everything

Spring's star clusters are more than pretty lights. They are each a glimpse into the Milky Way's story. From the youthful sparkle of M35 to the ancient NGC 188, and from M67's golden stars to the dense globulars M3, M53, and M68, each cluster has its own charm. Spring is the perfect time to explore and enjoy these stellar families, so set up your scope and observe them.

Phil Harrington *is a contributing editor of* Astronomy *and a lifelong observer of star clusters and other faint fuzzies.*



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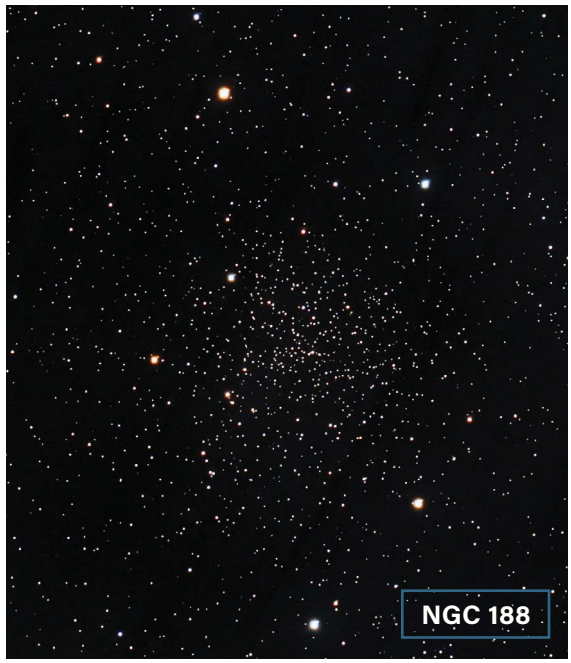

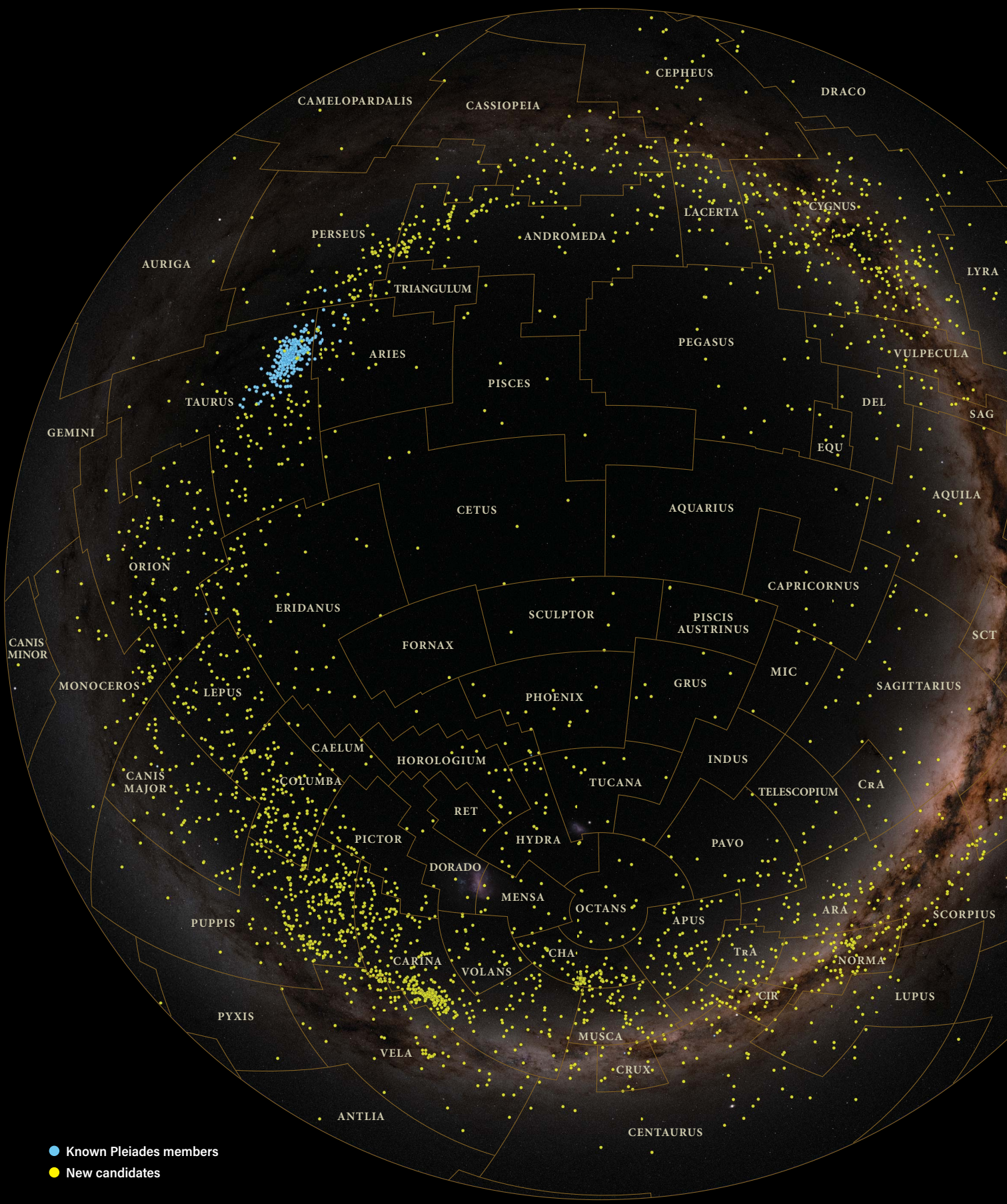
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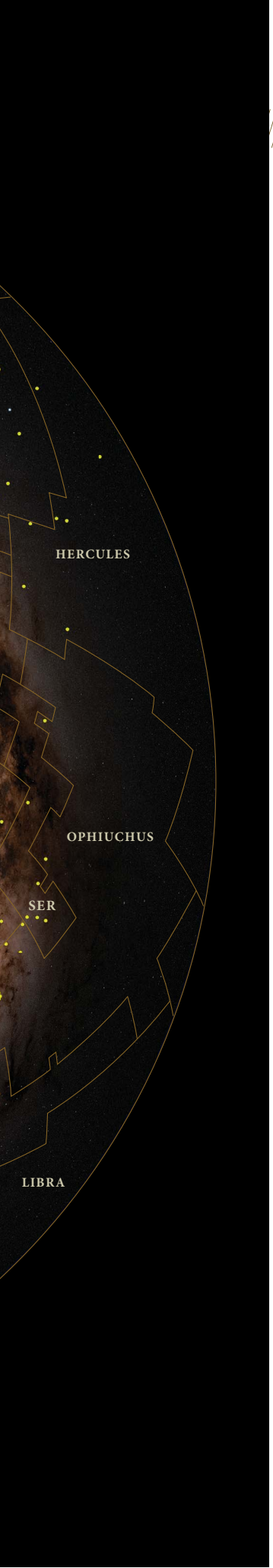
Known Pleiades members
New candidates



ASTRONOMERS FIND the Greater Pleiades Complex

Combining data from two space telescopes, a new study proves the famous Seven Sisters cluster is the core of a much larger, dissolving stellar family.

BY BROOKS MENDENHALL

FROM THE OLD TESTAMENT to the starry logo on your Subaru, the Pleiades (M45) are a cultural touchstone, springing up throughout human history. This star cluster has been mythologized across the globe, in cultures ranging from Aboriginal Australia to the Ancient Greeks, who envisioned them as the Seven Sisters of myth. Some scientists think similar stories are 100,000 years old, dating to before humans left Africa.

For most of modern human history, however, astronomers have known the Pleiades as a tight-knit family containing a few hundred to a thousand stars. A new study reveals we've only been looking at the tip of the celestial iceberg.

Astronomers at the University of North Carolina at Chapel Hill have discovered that the familiar Pleiades cluster is the bright core of a much larger association of stars they have named the Greater Pleiades Complex. In a study published Nov. 12 in *The Astrophysical Journal*, the team reveals this stellar family is between three and 20 times larger than previously thought, containing 3,091 member stars and spanning more than 1,950 light-years. The findings also demonstrate the merits of a new method for studying stellar evolution.

"This study changes how we see the Pleiades — not just seven bright stars, but thousands of long-lost siblings scattered across the whole sky," said lead author Andrew Boyle, a graduate student at UNC-Chapel Hill, in a press release.

Two-thirds of the night sky is shown in this image from NASA, with original members of the Pleiades cluster shown in blue. The 3,091 stars that were identified as relatives of the cluster and part of the newly discovered Greater Pleiades Complex are shown in yellow. NASA'S GODDARD SPACE FLIGHT CENTER; BACKGROUND, ESA/GAIA/DPAC; BOYLE ET. AL. 2025

Putting the family back together

The team's discovery combined data from two powerful space telescopes — NASA's Transiting Exoplanet Survey Satellite (TESS) and the European Space Agency's Gaia — as well as ground-based data from two major spectroscopic surveys, the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) and the Sloan Digital Sky Survey (SDSS).

Most stars, including our Sun, aren't born in isolation. They form in massive clouds of gas and dust, emerging in groups called open clusters. These stellar siblings are bound by gravity at first. But over millions of years, they drift

New findings suggest that the familiar Pleiades cluster, imaged above, is just the tip of the iceberg for a stellar family containing over 3,000 confirmed members. DYLAN O'DONNELL

apart and the cluster dissolves, making a given star's family tree difficult to trace. The stars that comprise the Pleiades cluster as we know it were born together some 100 million years ago and have mostly stuck together. But Boyle and his team wanted to know whether the known cluster might have even more siblings lost to time.

To find the rest of the Pleiades' family, the researchers developed a new method for tracking down an open cluster's members. First, they looked for stars traveling on the same orbit through the Milky Way as the stars in the Pleiades. Data from the Gaia satellite, which provides precise 3D positions and motions for billions of stars, allowed them to identify around 10,000 stars moving the same direction as the Pleiades' core. Since these stars were moving on the same path, it's possible that they were all drifting away from the same point of origin: the dusty nursery that birthed M45.

To further constrain their results, the team determined the ages of the 10,000 candidate stars using data from TESS as a cosmic clock. TESS was designed to hunt for exoplanets by searching for stellar dimming as transiting worlds pass in front of their stars. To that end, it has collected data on the brightness of millions of stars across more than 90 percent of the sky. The team used this data to look for patterns in the variability of the candidate stars' brightness. From them, they could determine the stars' rotation rates. Young stars — like those in the 100-million-year-old Pleiades — spin rapidly, while older stars have slowed down. The team identified the stars that shared a spin rate, and thus likely birth date, with the stars of the Pleiades cluster. This step whittled the list of 10,000 candidates down to a family of 3,091 related stars — the Greater Pleiades Complex.

"By measuring how stars spin, we can identify stellar groups too scattered to detect with traditional methods — opening a new window into the hidden architecture of our galaxy," Boyle said.

Verifying the results

The team performed a few final tests to verify their results. Stars born from the same giant cloud of gas and dust not only share the same orbit and spin rate, but also the same chemical recipe, determined by the blend of elements that made up the cloud itself. To confirm whether the stars had matching make-ups, the researchers turned to spectroscopy, a technique that splits starlight into its component colors to measure the precise abundances of elements. They analyzed data from LAMOST and SDSS to see whether a selection of the candidate stars were made of the same stuff as the Pleiades. The comparisons showed that the makeup of the candidate stars closely aligned with the makeup of the stars in the Pleiades cluster across several elements, meaning they were likely related.

Finally, they confirmed the origins of the Greater Pleiades Complex's 3,091 stars by analyzing their so-called traceback histories. Using the Gaia motion data — the same data used to find the initial candidates — the team ran computer simulations to rewind the stars' orbital paths. They showed that, based on their known motion, the entire collection of stars converged at the same location roughly 100 million years ago.

A new tool for stellar evolution

The study's "cosmic clock" method of measuring stellar spin now gives astronomers a powerful new tool. "We're realizing that many stars near the Sun are part of massive extended stellar families with complex structures," said co-author Andrew Mann, an associate professor of physics and astronomy also at UNC-Chapel Hill. This technique can be used to map the hidden architecture of our galaxy, with the team planning to apply it to other associations as part of the TESS All-Sky Rotation Survey. Just as this study reunited the Seven Sisters with their lost kin, the hope is that this method could one day help astronomers find the Sun's own lost siblings.

Brooks Mendenhall *is a staff writer at* Astronomy *and is based in Chattanooga, Tennessee.*

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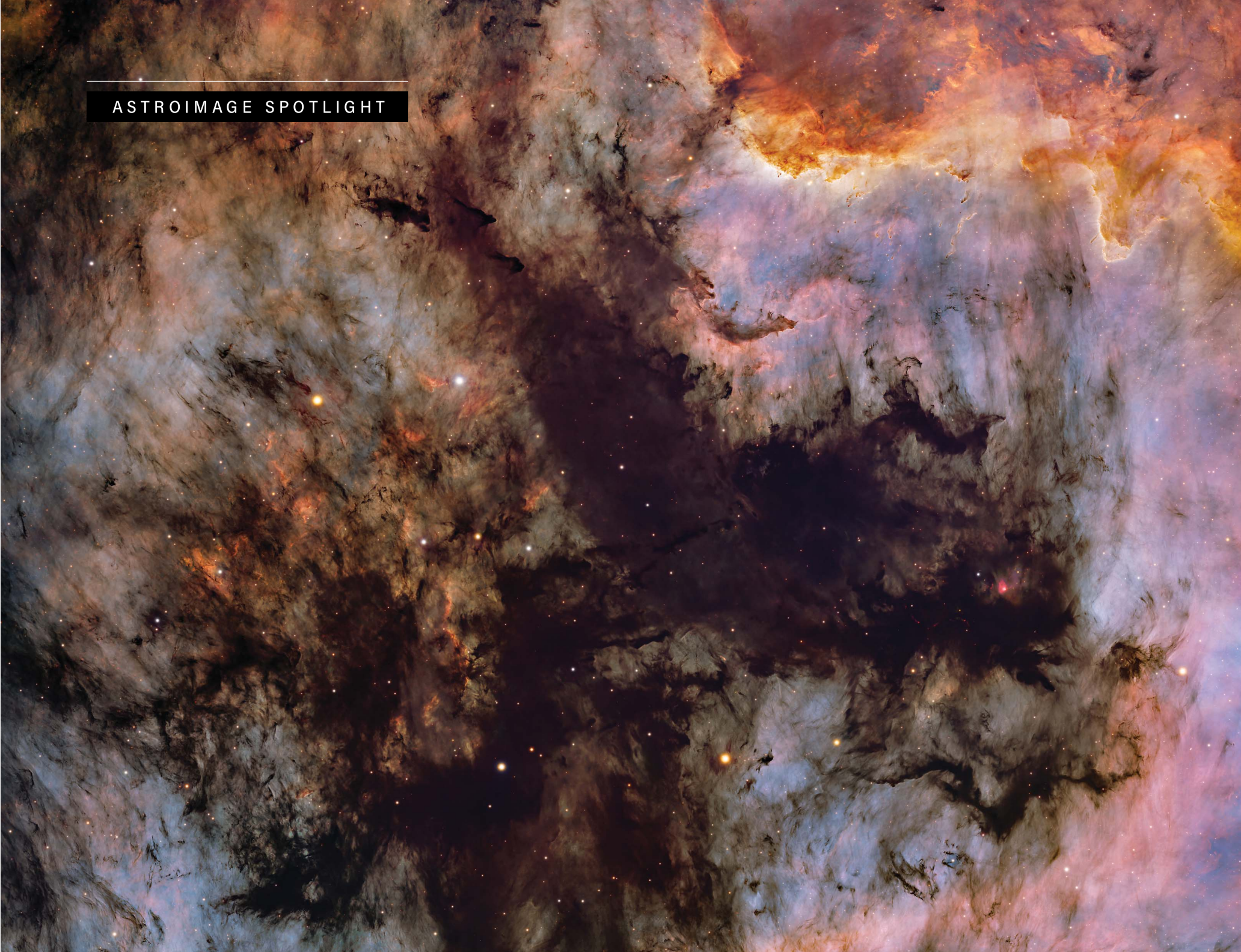

Negative space

Image by Jeffrey Horne/Drew Evans

THE NORTH AMERICA NEBULA (NGC 7000) and the Pelican Nebula (IC 5070) are two of the most famous objects in the northern sky, glowing in iconic shapes like the outline of the Atlantic coast.

But here, Jeffrey Horne and Drew Evans focus on the inky complex that occupies the gulf between them: the dark nebula LDN 935. Horne captured over 306 hours of exposure in narrowband filters from his Bortle 8.5 sky in Nashville, Tennessee; Evans took over 58 hours of broadband data from his backyard outside of Flagstaff, Arizona, under Bortle 1 skies.

Horne specializes in "wide and deep images of often-forgotten areas of the sky." In this scene, he said, "We were really hoping to see some brighter RGB dust in these dark areas, and there is some, but it is incredibly faint."

Horne used a 4.7-inch scope at f/5.6 with an APS-C format camera, while Evans used a 5.2-inch scope at f/6.9 with a full-frame camera, resulting in "almost a perfect match" of fields of view, said Horne. The sheer amount of observations also took dedication and perseverance to complete. "One of the things I love about Drew is that he is always pumped to collaborate," said Horne. "His 'Let's freaking go' attitude is incredible." **—Mark Zastrow**

Narrowband data // Nashville, Tennessee • Askar 120 APO • ZWO ASI2600MM • 306.6 hours of exposure in SHO filters

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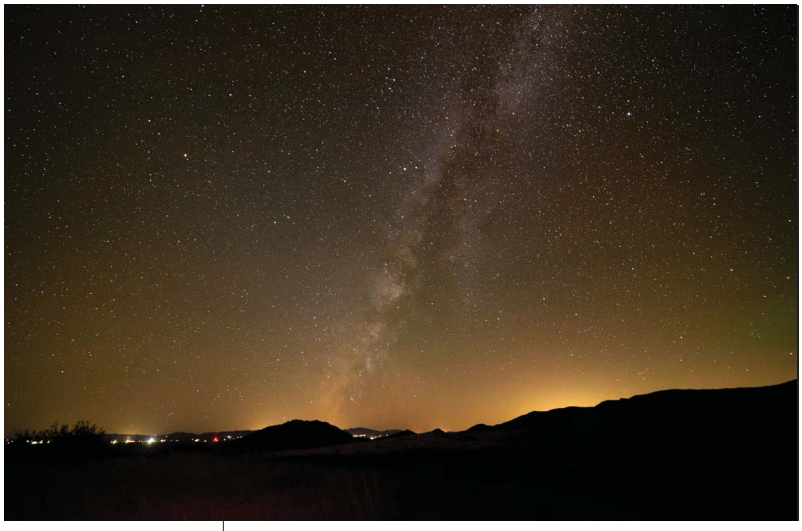
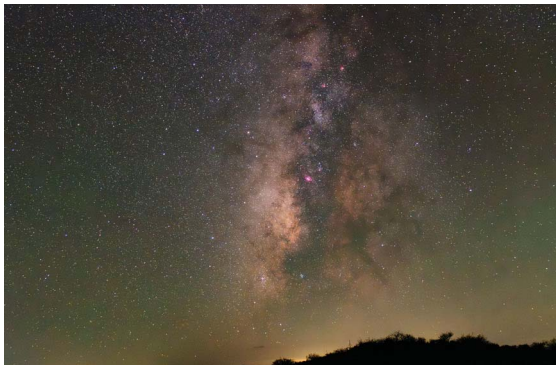
Modify your DSLR

The gains for imagers are immense.





The author took the Milky Way shot above through an unmodified Nikon D610 DSLR. The shot on the right was through a modified Nikon D7000 DSLR.
MOLLY WAKELING (2)

BY MOLLY WAKELING
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

There comes a point in many astrophotographers' lives when we realize that our standard DSLR just isn't going to cut it anymore, and there's just one reason why. There's a noticeable lack of red in astroimages, and the stock UV/IR filter over the sensor is the culprit. To better mimic the human eye, these filters have low transmission in the red region of the visible spectrum. But for imagers, that's where all the glowing hydrogen is that's scattered across the universe.

Whether you're shooting wide-field Milky Way nightscapes or long exposures of the Lagoon Nebula (M8) through a telescope, using an astromodified DSLR will bring much more color — particularly in the Hydrogen-alpha red region — to your images. (Note: I say DSLRs for short, but the same is also true for newer mirrorless cameras.) While your images may come out with an unfamiliar overall red cast, proper color-balancing techniques will get you to a better final product. I had long envied the colorful Milky Way nightscapes I've seen others take, but had been unable to replicate before I got a modified camera. Now, however, I'm taking much better shots.

There are two primary options: astromodification, which replaces the existing UV/IR filter with one that passes more of the red spectrum, and full spectrum conversion, which completely removes the UV/IR filter and replaces it with glass to maintain the focus point. The latter can work for those interested in infrared photography, but it can cause problems when using optics with any refractive elements due to ultraviolet and infrared light not being focused to the same point as the visible light. In this case, however, you can simply use a UV/IR cut filter somewhere in your optics train to regain normal use of the camera. And although the initial color balance looks much different, you can still use your astromodified DSLR for normal daytime photography as well just by adjusting the color balance.

While it is technically possible to do the mod yourself, I wouldn't recommend it unless you have some old DSLRs you don't mind breaking while you practice. Instead, there are several companies that are experienced at performing this service. My Nikon D7000 was modified by Spencer's Camera & Photo in Utah, which also modified two DSLRs for NASA to use aboard the International Space Station.

Why I would pay to modify a DSLR rather than just use one of my deep-sky astrophotography cameras paired with a lens, which are essentially already "modified" and have the added bonus of being cooled? The answer is that being tethered to a computer and a power supply makes shooting nightscapes difficult and less fun. DSLRs have the flexibility of having their own built-in computer, power, and control. With the higher red sensitivity, my modified DSLR is also better for aurorae and lightning storm-spawned sprites as well.

So it seems I've come full circle in my astrophotography career. I started with an ordinary DSLR, and now I find myself wanting to use a DSLR again — but this one better suited for capturing the true colors of the universe.

While it is technically possible to do the mod yourself, I wouldn't recommend it unless you have some old DSLRs you don't mind breaking while you practice.

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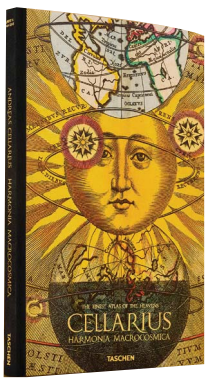

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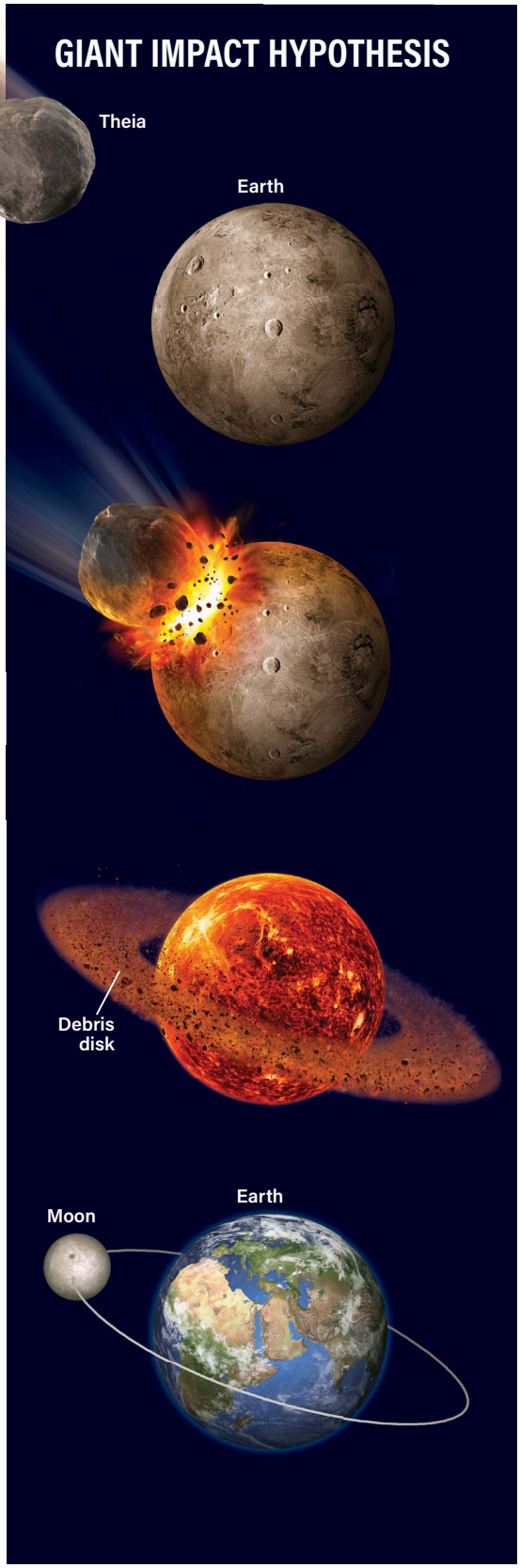


The Giant Impact Hypothesis posits that a Mars-sized planetismal called Theia slammed Earth. One possible resulting scenario suggests some of the debris from the collision formed the Moon, while iron from the planetismal became part of Earth's core. Without the Moon — and presumably that collision — Earth would have less iron at its core, and a far weaker magnetic field. The illustration at right shows the classical depiction of this scenario; recent simulations suggest the debris disk might have been very short-lived. *ASTRONOMY:* ROEN KELLY

Q | WHAT WOULD EARTH BE LIKE IF THERE WERE NO MOON?

Peter Allen Rhodes
North Bellmore, New York

A | Without the Moon, Earth's geology, biology, and climate — as well as human philosophy — would be different in many significant ways.

If Earth had no Moon, the postulated origin of the Moon through a collision between the proto-Earth and a Mars-sized object we now call Theia would never have occurred. The Earth/Theia collision shattered both worlds and the larger Earth attracted much of Theia's iron and heavier elements. The resulting larger iron core within Earth created a stronger magnetic field that protected the planet from the radiation effects of energetic solar particles, allowing the earliest life-forms to evolve. Without the shield of a strong magnetic field, the evolution of life on Earth would have taken a different path.

After its creation, the Moon was about 10 times closer to Earth than it is today. When Earth's oceans formed over 3 billion years ago, the greater gravitational pull from the Moon's proximity created titanic ocean tides hundreds of feet high that washed far inland. The violent churning of the oceans helped mix and distribute the waterborne chemistry that sparked the evolution of life on Earth. But with no lunar gravity driving the tides and assisting currents, those oceans would have become largely stagnant.

Even at its current distance, lunar gravity pulling on the tidal bulge creates friction between the water and the ocean basins, slowing Earth's rotation. Without the Moon, our days would be much shorter. And without the stabilizing effect of the Moon's gravity, our rotational axis would wobble, altering or periodically eliminating the seasons. Thus, without the Moon stabilizing the seasons, plant life could have evolved, but animal life may not have. Many plant and tree species are far more radiation- and harsh-climate-resistant than animal life, so a moonless Earth might be lush and green, but without the chirp of birds or the howl of a wolf.

Finally, even if humanity had evolved on a moonless Earth, only the distant, pinpoint planets and starry realm of the Milky Way would be our nightly companions. Archaeological evidence shows that 20,000 years ago, there was already interest in the Moon's cycles. Without the nearby Moon sparking our curiosity about other worlds, our space exploration program would be vastly different. Humanity might not even be a spacefaring species.

Life on Earth, and humanity itself, owes its existence and part of its legacy to the silver orb that circles our green Earth.

Robert Reeves
Author of Photographic Atlas of the Moon

Q SINCE THE UNIVERSE WAS VERY SMALL RIGHT AFTER THE BIG BANG AND YET IT CONTAINED THE SAME AMOUNT OF MATTER AS NOW, WOULD THE INTENSE GRAVITY HAVE SLOWED THE PASSAGE OF TIME?

Roger Reed
Pierre, South Dakota

A Shortly after the Big Bang, the density of the universe was greater than the inside of a neutron star … greater than the density of nuclear matter … greater than everywhere in space.

We know that neutron stars are so dense — they squeeze roughly twice the mass of the Sun into an object only the size of a small city — that their mass starts to warp local space-time around them severely. This causes a time-dilation effect, so time passes 1.9 times slower near the neutron star than it does for us.

The only clock that you can actually use to gauge what is happening is the clock that you carry. It ticks off what is called proper time as you move along your worldline — the path you trace in the universe as you move through it, living your life. If you traveled near the speed of light to Alpha (α) Centauri, you could literally get there in seconds by your proper time clock while observers back on Earth saw 4.3 years go by. Likewise, the neutron star time-dilation factor of 1.9 is only measurable with respect to distant clocks located where space-time is not distorted and gravity is weak, like Earth.

But there is no such distant place for the Big Bang. Soon after the Big Bang, the entire universe was filled with a dense plasma and every particle within it was traveling at nearly the speed of light. Every particle measured its own proper time as it moved along its torturous worldline through the mishmash of the Big Bang event. Within the small, hot, dense universe, there was no external, faraway clock outside these conditions against which to measure the time dilation experienced by all these particles at a given proper time.

IF HUMANITY HAD EVOLVED ON A MOONLESS EARTH, ONLY THE DISTANT PINPOINT PLANETS AND STARRY REALM OF THE MILKY WAY WOULD BE OUR NIGHTLY COMPANIONS.

Let's think back to our neutron star: If you have two nearby clocks both in the gravitational field of the neutron star, an observer with one clock would see an observer with the other clock experience a severe but different time dilation effect because they are located in different parts of the neutron star's gravitational field and traveling at different velocities. Near the Big Bang, the intensity of the gravitational field causes a similar "differential effect," but its magnitude is vastly greater and changing so rapidly in time that it is impossible to measure the differential time dilation experienced between particles carrying their own proper time clocks.

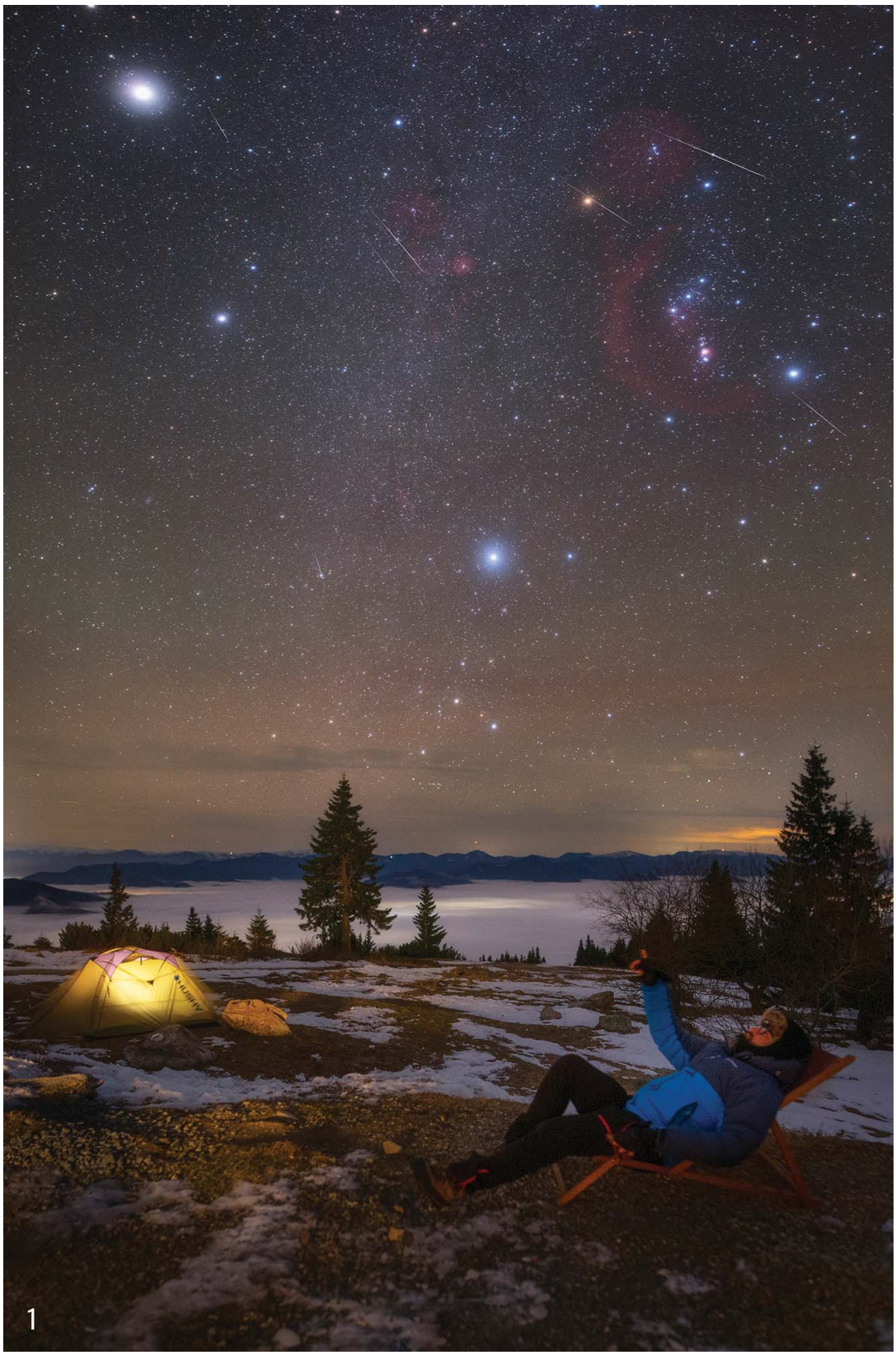
So, the answer to the question is that we cannot measure the slowing of time near the Big Bang because there is no "cosmic clock" outside of this dense plasma against which we could gauge such differences. Proper time is only what we measure on our own clock, whether that is a clock we hold here on Earth, for which the Big Bang occurred 13.8 billion years ago, or the clock of a particle shortly after the Big Bang, for which only 10^{-15} seconds has elapsed.

Sten Odenwald
Senior Outreach Coordinator, NASA HEAT Program, Kensington, Maryland

SEND US YOUR QUESTIONS

Send your astronomy questions via email to **askastro@astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Shortly after the Big Bang, the universe was made up of dense plasma, as imagined here, with the particles within it moving at nearly the speed of light. ANDRII, GENERATED WITH AI/ADOBE STOCK



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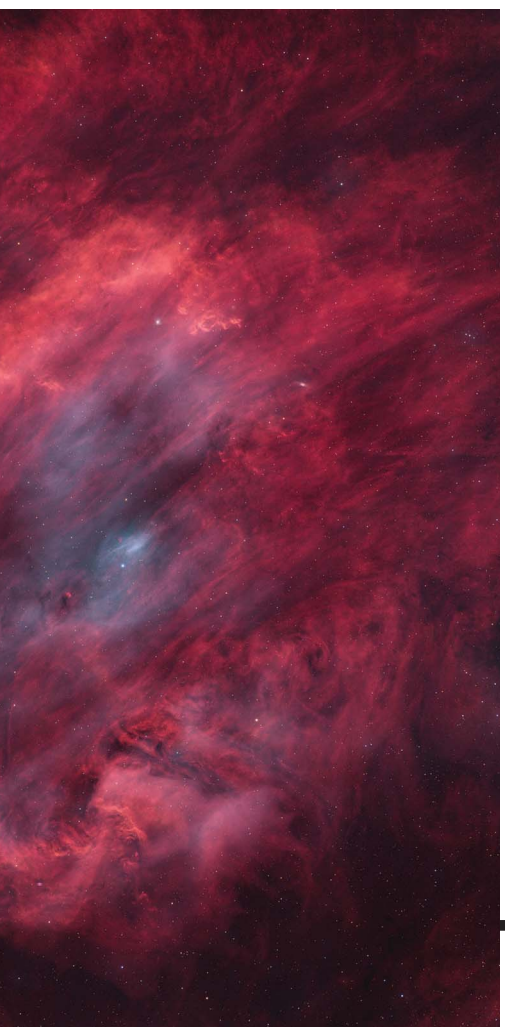

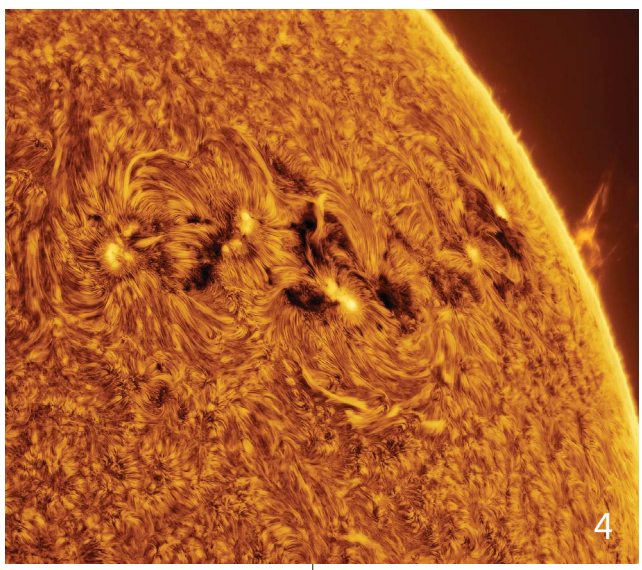

1. CAMP SHOWER
Geminid meteors streak above this photographer's campsite in Slovakia's Malá Fatra National Park. The scene was captured in a 15-second exposure at f/2 and ISO 4000 with an astromodified Canon DSLR and 24mm lens; meteors were imaged over a one-hour period to create this composite. ▪ ***Ondrej Králik***

2. A CLAM IN CYGNUS
Emission nebula Sharpless 2–119 in Cygnus is also known as the Clamshell Nebula. Its ringlike appearance is thanks to the shell of ionized gas — called a Strömgren sphere — surrounding an association of hot, massive stars. This imager took 49 hours of SHO exposure with an 8-inch RASA. ▪ ***Ryan Génier***

3. SOUTHERN SERPENT
This complex of dust snaking through the southern constellation Apus the Bird of Paradise is catalogued as Mandel-Wilson 9, also known as the South Celestial Serpent. It's an example of galactic cirrus or an integrated flux nebula, lit dimly not by a single star or cluster but the overall glow of the Milky Way. The imager took 46⅓ hours of exposure with a 6-inch f/3.3 scope in RGB filters. ▪ ***Vikas Chander***

4. THE SPOTTED SUN
Several sunspot groups — active regions AR 4136, 4139, 4143, and 4146 — approach the solar limb in this Hα image taken July 19, 2025, with a 6-inch f/25 refractor. ▪ ***Alessandro Carrozzi***

5. DEPARTURE DELAYED
A Full Moon rises Feb. 1 above Launch Complex 39B and the Artemis 2 mission's Space Launch System on the eve of its first wet dress rehearsal. The photographers captured this shot from Titusville, Florida, around 11 miles from the pad, with a Canon mirrorless camera and 800mm zoom lens. ▪ ***Chengcheng Xu/Tianyao Yang***

6. HOME ON THE RANGE
The Milky Way arches over a hut offering refuge to mountaineers on New Zealand's Arrowsmith Range. The photographer used an astromodified Fujifilm mirrorless camera to take two panoramas: the ground with a 23mm lens at f/2 and the sky with a 27mm f/1.4 lens and Hα and star glow filters. Subframes were 60-second exposures at ISO 800.
▪ ***Owain Scullion***

5

SEND YOUR IMAGES TO: readergallery@astronomy.com. Please include the date and location of the image, your mailing address, and complete photo data: telescope, camera, filters, and exposures.

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IN THE SPIDER'S SHADOW

When deep-sky observers contemplate the Large Magellanic Cloud (LMC), the Milky Way's largest satellite galaxy, they immediately think of the Tarantula Nebula (NGC 2070). And no wonder — this emission nebula is the largest star-forming region in the local universe. But the LMC offers much more. Just 0.7° south of the Tarantula lies another impressive stellar nursery astronomers have cataloged as N159. This Hubble image showcases a small part of the 150-light-year-wide nebula, which boasts many newly formed stars. The most massive of these suns glow blue and radiate enough ultraviolet energy to ionize surrounding hydrogen, giving the nebula its characteristic reddish hue. ESA/HUBBLE & NASA, R. INDEBETOUW

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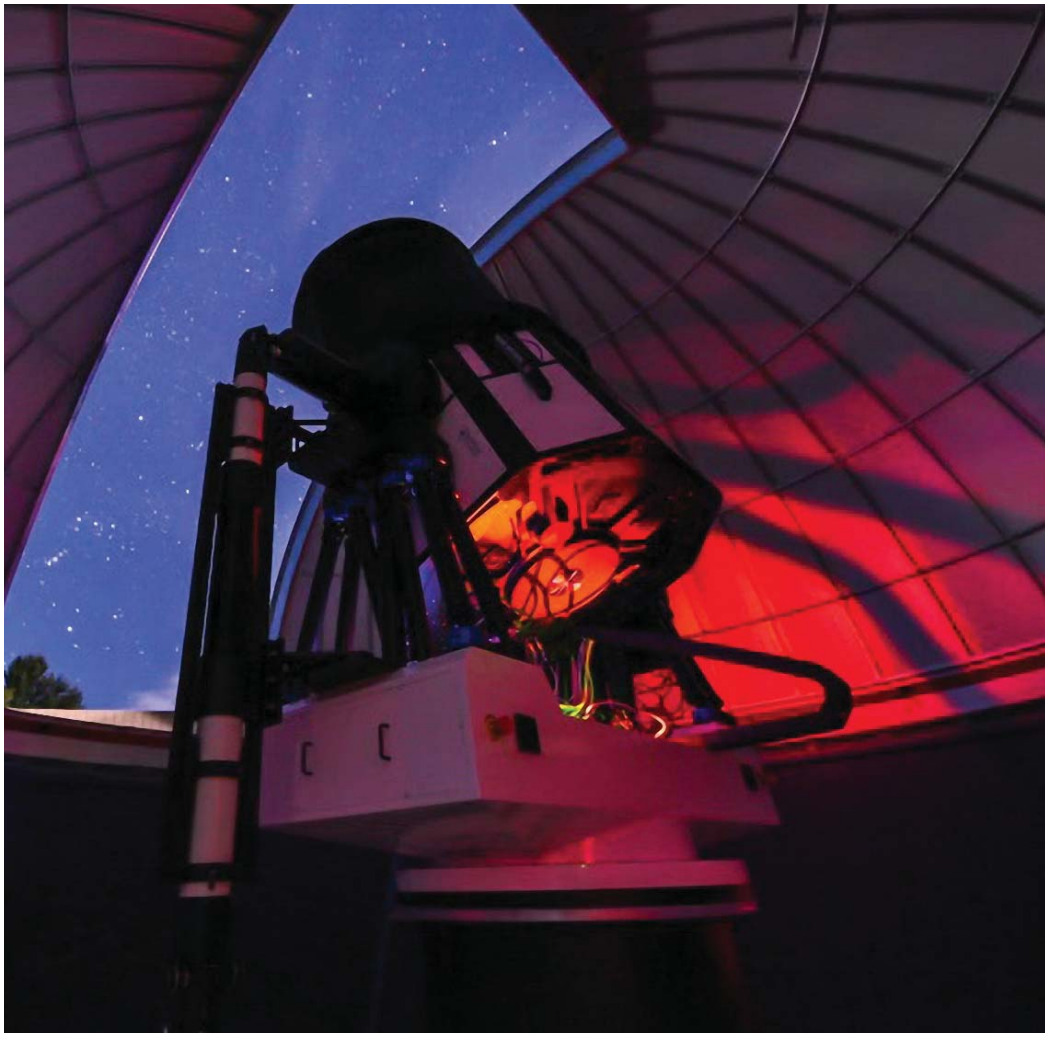

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July 2026
Jupiter's last evening gasp

As July begins, three planets adorn the early evening sky. Look toward the northwest and you'll see **Venus**. The planet shines brilliantly at magnitude –4.1 and shows up easily 30 minutes after sunset. It creeps slowly away from the Sun and into a darker sky as July progresses.

Venus also becomes more attractive through a telescope this month. On July 1, its disk measures 16" across and is 69 percent lit. By the 31st, it spans 21" and appears 56 percent illuminated. The planet's gibbous phase shows up nicely in small scopes, though the view will improve noticeably in the next few months.

You'll find **Jupiter** to the lower left of Venus. The giant planet shines at magnitude –1.8, bright enough to appear conspicuous against a twilight sky. Unfortunately, Jupiter succumbs to the Sun's glare within a couple of weeks and reaches solar conjunction July 29. It will return to view before dawn in late August.

The planet's low altitude means a telescope won't provide the best views of the gas giant's dynamic atmosphere. However, you should still be able to see its four bright Galilean moons.

Innermost **Mercury** is disappearing even more rapidly than Jupiter. Look for it 5° to the giant planet's lower left on the evening of the 1st. Mercury glows at 2nd magnitude and will be difficult to spot with the naked eye. A telescope reveals the inner world's beautiful crescent phase.

After passing through inferior conjunction July 13, Mercury climbs into view before dawn. You can find it some 6° high in the east-northeast about 45 minutes before sunrise. At magnitude 0.5, it should be fairly easy to spot. And a telescope once again shows the planet as a pleasing crescent.

Beautiful **Saturn** rises in the east just before 1 A.M. local time in early July and some two hours earlier by month's end. The ringed world shines at magnitude 0.6 against the dim background stars of southern Pisces the Fish, just across the border from Cetus the Whale.

A telescope provides stunning views of Saturn. The sharpest images come when the planet climbs highest in the sky shortly before morning twilight starts to paint the sky. In mid-July, you'll see Saturn's globe measuring 18" across the equator while the rings span 41" and tilt 9° to our line of sight.

In addition to the lovely rings, watch for the planet's brightest satellites. Any telescope reveals 8th-magnitude Titan, the solar system's second-largest moon. And a 10-centimeter instrument gathers enough light to reveal the 10th-magnitude glows of Tethys, Dione, and Rhea. Also keep an eye out for Iapetus. This two-faced moon shines at 10th magnitude around its greatest western elongation in mid-July. It then lies some 9' from Saturn.

The final naked-eye planet, **Mars**, rises about three hours before the Sun all month. The magnitude 1.3 Red Planet begins July against the backdrop of Taurus, beautifully placed between the Pleiades and Hyades star clusters. Mars moves steadily eastward relative to the background stars, ending the month nearly between the tips of the Bull's horns.

Mars remains a disappointing telescopic subject, showing a featureless disk just 5" in apparent diameter. Better views await when the planet comes closer to Earth this spring.

The starry sky

Star colors have always fascinated me, and I especially enjoy pointing out these colors when school classes visit my planetarium. Many schoolkids have yet to notice the distinctly orange-red color of Antares in Scorpius the Scorpion, which passes nearly overhead on July evenings. Because most people associate the color red with heat, I always like to mention that red stars actually have cooler surface temperatures than yellow or blue-white ones.

Experienced stargazers know that Antares appears reddish, but most casual observers don't realize that Gacrux (Gamma [γ] Crucis), the star that marks the top of the Southern Cross in the constellation Crux, also has an orange-red color. Although it's easy to see the color of this magnitude 1.6 star, I think the reason why fewer people realize it's red is that the Australian flag shows all five stars in Crux as white. For a significant portion of the population, the flag is how they perceive this constellation's star colors.

The flags of Brazil, Samoa, and Papua New Guinea also show the Southern Cross and, as on the Australian flag, they all depict the stars as white.

Intriguingly, this is not so on the flag of New Zealand. Its flag shows the Cross as having four red stars, each with a white border. So, none of the five crosses on these flags shows the stars in their true relative colors.

Still less known is that the color of the star Ginan (Epsilon [ε] Cru) also differs from the blue-white tints exhibited by most of Crux's stars. Magnitude 3.6 Epsilon appears yellow-orange, but because it shines more dimly than Antares or Gacrux, this delicate hue doesn't show up easily to the naked eye. Ginan has a spectral type of K and has a warmer surface temperature compared with the M stars Antares and Gacrux. Try observing Ginan with binoculars or a telescope. Their superior light-gathering power should help you perceive its color. Another way is to take an out-of-focus picture of the Southern Cross — try it, and see the curious result.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. July 1
8 P.M. July 15
7 P.M. July 31

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

JULY 2026

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

4 Mars passes 0.1° south of Uranus, 5h UT
Mercury passes 10° south of Pollux, 11h UT

6 Earth is at aphelion (152.1 million kilometers from the Sun), 17h UT

7 The Moon passes 5° north of Neptune, 3h UT
Last Quarter Moon occurs at 19h29m UT
The Moon passes 7° north of Saturn, 22h UT

8 Neptune is stationary, 4h UT
Asteroid Melpomene is at opposition, 20h UT

9 Venus passes 1.1° north of Uranus, 14h UT
Asteroid Flora is at opposition, 22h UT

11 The Moon passes 5° north of Uranus, 7h UT
The Moon passes 3° north of Mars, 15h UT

13 Mercury is in inferior conjunction, 1h UT
The Moon is at perigee (359,112 kilometers from Earth), 7h57m UT

14 Mars passes 5° north of Aldebaran, 7h UT
New Moon occurs at 9h44m UT

15 The Moon passes 2° north of Jupiter, 3h UT

17 The Moon passes 0.5° south of Regulus, 1h UT
The Moon passes 2° south of Venus, 17h UT

21 First Quarter Moon occurs at 11h06m UT

23 Mercury is stationary, 17h UT

24 The Moon passes 0.6° south of Antares, 22h UT

25 The Moon is at apogee (405,548 kilometers from Earth), 16h45m UT

26 Asteroid Juno is at opposition, 17h UT

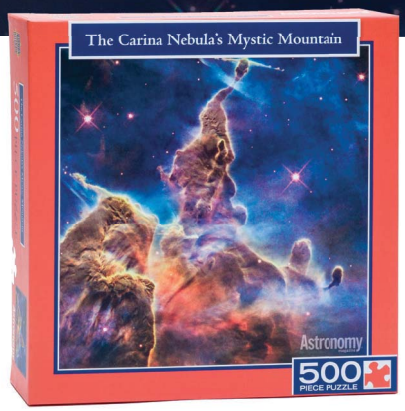
27 Pluto is at opposition, 7h UT
Saturn is stationary, 23h UT

28 Asteroid Bamberga is at opposition, 9h UT

29 Jupiter is in conjunction with the Sun, 12h UT
Full Moon occurs at 14h38m UT

30 Southern Delta Aquariid meteor shower peaks

EXPLORE THE UNIVERSE



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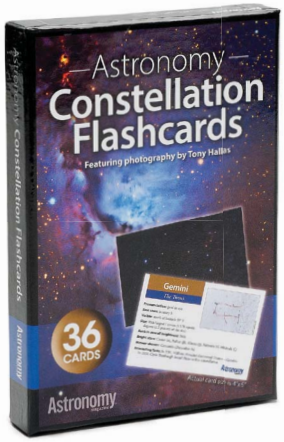

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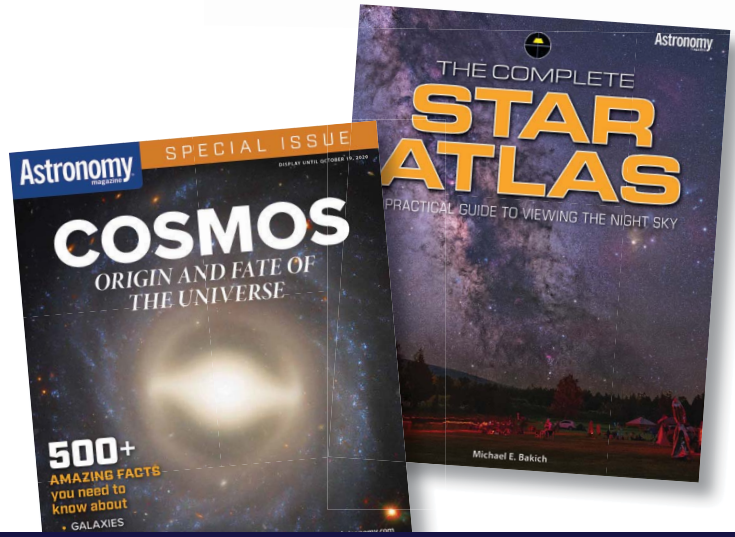

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